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Review

Review of Serious Energy Games: Objectives, Approaches, Applications, Data Integration, and Performance Assessment

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Abstract: In recent years, serious energy games (SEGs) garnered increasing attention as an innovative and effective approach to tackling energy-related challenges. This review delves into the multifaceted landscape of SEG, specifically focusing on their wide-ranging applications in various contexts. The study investigates potential enhancements in user engagement achieved through integrating social connections, personalization, and data integration. Among the main challenges identified, previous studies overlooked the full potential of serious games in addressing emerging needs in energy systems, opting for over-simplified approaches. Further, these studies exhibit limited scalability and constrained generalizability, which poses challenges in applying their findings to larger energy systems and diverse scenarios. By incorporating lessons learned from prior experiences, this review aims to propel the development of SEG toward more innovative and impactful directions. It is firmly believed that positive behavior changes among individuals can be effectively encouraged by using SEG.

Keywords: serious game; energy; demand side management; behavior change

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1. Introduction

The increasing demand for electricity due to the electrification of heating/cooling systems in buildings and the transport system, along with the alarming rise in carbon emissions from conventional energy sources, such as coal, oil, and natural gas, compelled the world to seek alternative solutions. Despite the increasing integration of renewable energy, its availability is still unpredictable and restricted. Therefore, the relentless pursuit of innovative approaches to ensure sustainable and resilient energy systems must be continued [1]. The European Council established the European Union's (EU) climate action strategies to achieve a climate-neutral economy with net-zero greenhouse gas emissions by 2050 [2]. By 2030, the EU set key targets, which include reducing greenhouse gas emissions by at least 40% compared to 1990 levels, achieving a minimum of 32% renewable energy share, and improving energy efficiency by at least 32.5% [3,4]. It is noteworthy that the prior strategies outlined by the European Council aimed to achieve a 27% increase in energy savings and a 27% share of renewable energy [5], which highlights the necessity of further efforts and advancements in implementing sustainable energy practices and technologies to meet these ambitious targets.

Achieving the aforementioned objectives necessitates diverse actors taking a wide range of measures, from enhancing energy efficiency in buildings and the further development of renewable energy technologies to nudging behavior change in energy use. Numerous research studies created significant insights into the technological challenges of balancing energy supply and demand [6]. These challenges encompass a wide range of factors, such as the capacity of energy systems to facilitate affordable access to energy services and ensure the security and reliability of energy supply [7].

While technological advancements play a vital role in providing sustainable alternatives, the success of our efforts ultimately hinges on our ability to transform human behavior [8]. Increasing awareness of energy-related practices in different sectors is a cost-effective approach to promoting sustainable energy transition in societies, yet changing human behavior remains a significant challenge [9].

The initial effort to enhance public consciousness regarding energy usage was established upon the premise that energy is "doubly invisible", given that the quantity and influence of energy are abstract concepts [10]. The intangibility of energy renders it arduous for society to conceptualize it, whereas conventional energy bills are unable to completely articulate the intricate and dynamic nature of energy consumption patterns [11]. In recent years, there was a growing research interest in increasing the perceptibility of energy usage through the implementation of diverse strategies, such as providing visibility for energy use [12], and the real-time visual display of consumption levels [13]. For instance, in-home energy displays are effective in average savings ranging from 4% to 12%, with over 20% peak savings [14]. Nevertheless, in aiming for lasting behavior change, the effectiveness of this intervention primarily depends on user engagement. Accordingly, the visualization mechanisms should be thoughtfully designed to render the feedback readily understandable to users, and provide them with insights into their energy consumption patterns and routines [14]. Innovative promotion of energy applications involves an interactive, collaborative, and visual approach to maintain user engagement and allow service providers to adapt to users' capabilities [15], which necessitates the design, development, implementation, and active use of innovative systems, technologies, and behavior change strategies [16].

Intervening in the social routines of people through traditional education programs is challenging, as they may not have the same reach and impact as modern media platforms. In recent decades, serious games, particularly cross-media-oriented and multi-player-involved role-playing games, emerged as a key approach to addressing this challenge [17,18]. There is increasing evidence that certain individuals are more receptive to receiving information and feedback presented in a fun and engaging manner. Therefore, implementing game-based and gamification strategies could be a viable solution to address this need [19].

Gamification refers to incorporating game elements, mechanics, and design principles into non-game contexts. It involves applying game-like features, such as points, badges, leaderboards, and challenges, to engage and motivate individuals, encourage desired behaviors, and enhance their overall experience [20].

With the swift progress of digital and mobile technologies, digital game-based learning emerged as a prominent approach that can overcome the constraints of time and location and enhance accessibility and engagement for learners [21]. Hamari et al. [22] introduced three key components of serious games. Firstly, initial motivational goals that encourage individuals to engage with the game. Secondly, psychological outcomes similar to traditional gaming environments, such as increased enjoyment, motivation, and engagement, and finally, desired behavior patterns established within and beyond the game context. Among other gamification models is the Octalysis framework developed by Argilès and Chou [23] with eight core drives: Epic Meaning and Calling, Development and Accomplishment, Empowerment of Creativity and Feedback, Ownership and Possession, Social Influence and Relatedness, Scarcity and Impatience, Unpredictability and Curiosity, and Loss and Avoidance. Since teachers recognized the potential of serious games, the education was an early adopter of this approach. Serious games demonstrated high motivation levels and offer instant feedback, making them adaptable to learners' skill levels. They also facilitate effective knowledge transfer and provide opportunities for repetition [24]. Moreover, it is worth noting that gamification was successfully implemented in various domains beyond education, including health (for general health, rehabilitation, mental disorders, and educating patients) [25], business (for motivating employees and retaining loyal customers) [26,27], and government (for promoting public participation) [28–32].

Gamification is also used to promote sustainable behaviors, adopt resource-efficient practices in the users' lives, and mitigate climate change [33]. The role of serious games in developing 21st century skills that can lead to addressing the climate crisis is a potential asset [34]. In this context, some of the main developed games can be categorized as sustainability education (e.g., 'Factory Heroes', for improving the sustainability leadership skills in manufacturing [34]), transportation and air quality (e.g., 'Mordor Sharper', for incentivizing the carpooling system [35]), waste management (e.g., 'WasteApp' for increasing recycling [36]), energy-related applications (which are discussed in this paper), and water conservation (e.g., for increasing community engagement for water-related event preparedness such as planning to conserve water during drought [36]). The Smart H_2O project, with the objective of establishing a positive feedback loop between water utilities and users, provides information about water consumption in almost real time and enables water utilities to develop strategies for water supply [37]. This project uses a gamification approach to encourage users to modify their water consumption habits, utilizing various incentives, such as virtual, physical, and social rewards to promote competition between users [38].

Web platforms also emerged to serve as a directory of serious games on sustainability, such as Games4Sustainability, where games centered around the United Nations' Sustainable Development Goals are presented [39]. It also provides a classification of both digital and non-digital games based on their intended age range and learning objectives [40].

Serious energy games (SEGs) as interactive experiences that engage users to various energy applications are gaining prominence as an innovative approach, particularly in the realm of energy usage, distributed generation, and interaction with energy markets. An early effort in SEG is the PowerHouse [41], which was developed to motivate the reduction in energy consumption in households in the short term through simulation-based games. After the success of initial SEG in reducing energy consumption in households, researchers expanded their focus to explore the potential of this technique for other target groups and to incorporate real data into the games (e.g., Power Agent [42] and Power Explorer [43]), which allowed for more accurate simulations and personalized experiences for users. Most of these games apply the points–badges–leaderboards model, known as 'four-square,' which is prevalent in serious games [22]. This model incorporates game-like elements and rewards to encourage interaction, engagement, and the establishment of new behavior patterns. These elements motivate continued interest and interaction, while social comparison on leaderboards and social media platforms reinforces the desired behaviors [11].

There are few reviews in the domain of SEG. These reviews focus mainly on the potential of SEG, particularly on energy efficiency as the core energy application and user engagement [18,42,44]. To the best of our knowledge, we have not come across any reviews that thoroughly explore the wide range of energy applications and investigate the potential enhancements in engagement through the integration of social connections, personalized game environments, and data integration. The study assists the serious energy game developers and researchers to draw insights from previous experiences while addressing emerging issues and novel challenges in the field. In Section 2, the objectives and applications of prior research efforts are delved into. Specifically, the transfer of information and engaging users in these studies is examined. Furthermore, it explores the utilization of various energy applications within gamified environments, specifically focusing on demand-side management (DSM) in SEG. The role of social connection and personalization is also explored in the section, as these aspects gained prominence in recent applications. In Section 3, the integration of data sources into SEG is focused on, taking into consideration the advancements in data collection methods facilitated by emerging technologies. In Section 4, the evaluation of user performance within SEG, as well as the assessment of the game application itself, is investigated based on previous studies. Finally, in Section 5, the findings derived from this study are presented, and suggestions for future research are provided. The suggested areas for further investigation primarily focus on:

- Incorporating advanced behavioral change models by contextualizing the intervention in the process of behavioral change, including precontemplation, contemplation, preparation, action, and maintenance steps.
- Adopting a comprehensive approach to address various aspects of DSM, through establishing interactive feedback loops between operators and users.
- Increasing sample sizes and study durations to enhance the applicability of research outcomes.

2. Objectives and Applications of Serious Energy Games

The energy transition is crucial for achieving a sustainable future. Still, one aspect that is often overlooked is the complexity of educating individuals on the benefits, urgency, and intricacies of renewable energy development and energy efficiency [24].

A properly designed serious game serves as an experimental platform that can effectively address multiple factors and explore different variables. This approach provides the necessary abstraction and flexibility for experimentation, scalability, and innovation within the energy behavior change context.

To take advantage of the findings and developments from a series of empirical research projects in the realm of SEG, it is beneficial to analyze their implementation of energy applications. These projects provided valuable insights and learning opportunities, including lessons from their outcomes and failures. By examining these findings, we can establish a solid groundwork for further investigation into possibilities and opportunities within the field.

An overview of the reviewed research projects is presented in Table 1. These projects were conducted between 2011 and 2021 and were sourced from scholarly publications. The table provides a comprehensive summary of the research studies, including details such as project name, type of game, study duration, medium of feedback, target group, study area, and study region.

According to Wu et al. [18], SEG can be classified into three categories based on the degree of end-user engagement: education-oriented, simulation-oriented, and application-oriented serious games. However, it is important to note that these categories are not mutually exclusive, with significant overlap between them. The latter categories often build upon and incorporate elements of the former ones. For instance, simulation-oriented games also have educational potential, and application-oriented games can integrate both educational and simulation aspects. This study also adopts the same classification to categorize SEG in Table 1. The categories are defined as follows:

- Education-oriented serious games: games that focus on energy consumption aim to raise awareness and shape behavior by utilizing game technology and design principles. These games provide virtual experiences and data related to energy conservation, using simplified real-life complexities and offering immersive learning environments to develop critical thinking and motivation. However, transferring of knowledge from these games to real life may pose challenges.
- Simulation-oriented serious games: games that aim to guide users in reducing energy consumption and exploring renewable energy options. These games utilize real-life energy data and encourage energy-related discussions. Compared with education-oriented serious games, these games connect gameplay to real-life behaviors by suggesting home-specific efficiency improvements, reducing the gap between the virtual world and reality. However, in these games, the collected data are condensed rather than detailed, and calculations are not automatically calibrated.
- Application-oriented serious games: games that utilize real or real-time data to provide engaging and practical experiences for users in various domains. These games go beyond entertainment, serving as effective training, learning, and problem-solving tools. By incorporating real-world data, users can immerse themselves in simulated environments that closely resemble their field's challenges, enhancing their knowledge and abilities. These games offer a dynamic and authentic learning experience, bridging the gap between theory and practice.

The duration of the studies varies, ranging from short sessions lasting as little as 30 min to long-term investigations lasting up to two years. These studies targeted diverse groups to examine the impact of serious games on energy-related behaviors and practices. The selection of these target groups is determined by multiple factors, such as access to the target group, the necessity of intervention for a specific group, access to smart technologies, and game mechanics. Notably, domestic energy users were the primary focus of most of these studies, highlighting the importance of engaging this particular group. However, less is known about the challenges of applying SEG for different populations and sectors. For instance, Mendez et al. [45] focused on the university campus since they found it to be an ideal starting point to promote interaction between energy users and the city to improve energy awareness.

In some research studies, the target group is selected based on social criteria. Social housing, a vulnerable segment of the housing sector facing high financial pressures, is considered one of the groups most severely affected by fluctuations and increases in fuel prices. It is reported that the social housing population in Europe faces 2.5 times more difficulty adequately heating their homes than the general population [11]. Research was conducted to address financial concerns and improve housing conditions within the social housing sector by utilizing SEG [11,46,47].

While previous research explored the use of serious games for energy consumers, Polyanska et al. [48] specifically focused on the application of serious games for energy companies. Drawing on the framework proposed by Figol et al. [49], two distinct types of gamification were identified: external gamification, which focuses on increasing consumer loyalty and company revenue, and internal gamification, which aims to enhance the productivity of personnel. Considering this distinction, Polyanska et al. implemented this tool in the management of energy companies in Ukraine and reported that using gamification tools could facilitate the support of energy policy and promote the effective integration of Ukrainian energy companies into the EU energy market [48].

In some studies, participants were specifically chosen from a group of high-energy consumers based on the assumption that they would have a greater potential for energy savings [50]. Including high-energy consumers allowed for a more targeted approach to understanding the factors influencing energy consumption patterns and identifying effective strategies for reducing energy usage.

Table 1. Summary of the literature on SEG.

References	Project Name (Acronym)	Type of Game	Duration of Gameplay	Medium(s) of Feedback	Target Group Types	Study Area	Study Region
[51,52]	EnerGAware (Energy Cat)	Application-oriented	24 months	Application	Social tenants	House	UK
[45]	Gamified HMI	Application-oriented	N/A	HMI	Students and professors	University campus	Mexico
[53–55]	enCOMPASS	Application-oriented	12 months	Mobile application	Households, school classes, office employees	House School Public buildings	Germany, Greece, Switzerland
[56–58]	Powersaver Game	Application-oriented	least five weeks	Web-based application	Households	House	Netherlands
[24]	We Energy Game	Simulation oriented	Less than 30 min	Web-based application	Energy cooperative members business, municipality representatives, students	Virtual city	Netherlands
[59]	EnergyElastics	Application-oriented	N/A	Mobile application	Households	House	USA
[60]	HotCity	Education-oriented	Unlimited	Mobile application	Individuals	City	Austria (Vienna and Graz)
[61–63]	Social Mpower	Simulation-oriented	30 min	Mobile application	Households	Virtual house	N/A
[64]	Energy Piggy Bank	Application-oriented	One week	Mobile application	Households	House	Sweden
[65]	Power House	Application-oriented	Unlimited	Mobile application	Households	House	USA
[50]	EnergyLife	Application-oriented	Three months	Web application adapted for touch screen-enabled mobile devices.	Households	House	Northern and Southern Europe (Finland and Italy)
[47]	Smarter household	Application-oriented	N/A	Mobile application	Social housing	House	UK
[66]	Social Power	Application-oriented	18 months (3 months pre-intervention, 3 months intervention, 12 months post-intervention)	Mobile application	Households	House	Switzerland

2.1. User Engagement and Information

Several research projects show that public perception of climate change does not fully align with the urgency of the issue, and the public gives a low priority to climate change policy making compared to other societal problems [24,67]. Some investigations suggested that endeavors to communicate and educate about sustainability have not met expectations. For example, while sufficient information were provided, the presentation methods were not convincing enough to effectively convey the message [68,69]. Efforts to raise awareness about energy consumption aim to reduce electricity consumption, which can lead to cost savings of 5% to 15% with little to no investment required [70,71]. This fact incentivized some researchers to investigate incorporating innovative energy-saving features [45].

Moreover, the literature emphasized the importance of engaging customers in smart grid initiatives [72]. As an example, whether deploying smart meters alone can effectively influence the energy-related behavior of residential customers is a topic of debate [73]. In this context, many studies provided evidence to support the effectiveness of integrating interactive interfaces alongside smart meter technologies [59,66,74,75]. This integration allows for the implementation of participatory and context-specific interventions that enhance users' awareness of their energy consumption and empower them to take proactive steps towards reducing their energy usage. Specifically, in a study conducted by Wemyss et al. [66], the Social Power application was designed as a complementary tool for the smart meter rollouts in Switzerland and leveraging their added advantages.

User engagement relies heavily on the provision of information to consumers. This information serves as a crucial element in shaping their energy consumption behaviors. Darby [76] presented one of the most widely accepted classifications for feedback information as direct and indirect. On the one hand, direct feedback involves presenting raw information from energy meters or display monitors, offering immediate and easily accessible consumption feedback. On the other hand, indirect feedback involves processing the data before presenting it to the user, often through energy bills, which can result in delays in providing feedback. Direct feedback allows for user control and comprehensive representation of energy feedback, while indirect feedback offers post-processed information. The distinction between direct and indirect feedback relates to the accessibility and latency of the feedback and the level of data processing involved before reaching the user [77]. Darby [76] suggests that a well-designed combination of direct and indirect (e.g., accurate billing) feedback system is essential for achieving long-term sustainable energy consumption behaviors.

In comparison, energy bills provide limited information on energy consumption and lack actionable insights for users [78]. The lack of information on everyday energy consumption, primarily limited to monthly or yearly energy bills that offer only a general overview, makes it challenging for households to understand how and when energy is used in their daily activities [79]. Consequently, misconceptions can arise, such as underestimating the energy savings obtained through energy-efficient behaviors such as enhancing home insulation and using more efficient equipment while simultaneously overestimating the energy savings derived from curtailment behaviors such as turning off lights [80].

To enhance the engagement of feedback beyond gamification features, SEG can offer consumers various types of information, including:

- Simple information: this includes basic details about energy usage, such as current energy consumption levels or historical data.
- Conjunctive information: this type of information compares the consumer's energy usage with that of similar households or benchmarks, allowing for better understanding and context.
- Tips/Advice: information in the form of tips and advice can help consumers identify specific actions to reduce their energy consumption and make more sustainable choices.
- Forecast information: forecasting provides consumers with insights into future energy demand and prices, enabling them to plan their energy usage more efficiently.

- Demand response (DR) and statistics: this type of information involves sharing grid and/or market data such as the system balancing status, peak demand periods, pricing structures, and other statistical information related to energy consumption.

From another perspective, Wu et al. [18] categorized the information provided in SEG for user engagement based on their level of education into four levels:

- Level 1: visualization of energy consumption to improve end-user understanding.
- Level 2: delivery of energy-related knowledge to the end-users.
- Level 3: delivery of energy-related knowledge with a feedback mechanism to prompt behavior change.
- Level 4: enhanced engagement and behavior change through multiplayer interactions or involving the end-users family and friends via social media.

In another classification by Zangheri et al. [81], information types in energy feedback applications are classified as real-time, appliance disaggregation, social comparison, historical comparison of energy consumption, energy consumption rewards, and energy efficiency advice. Games are well suited for conveying information as they provide a contextualized environment where various factors of influence can be compared.

2.2. Demand Side Management

In the domain of SEG, researchers pursued innovative solutions to tackle pressing energy demand challenges. In this section, we reviewed these cutting-edge approaches within the context of DSM.

DSM is defined by Gellings as "planning and implementation of those electric utility activities designed to influence customer uses of electricity in ways that will produce desired changes in the utility's load shape" [82]. DSM has diverse effects on power systems, encompassing the electricity market, environment, power system operation, and reliability. In the electricity market, consumers benefit from incentive payments, while utilities experience reduced costs, decreased load losses, and increased system efficiency. DSM initiatives enhance economic dispatch, augment electricity market performance, and mitigate market risks. Regarding power system operation, DSM aids in maintaining voltage stability, easing transmission congestion by smoothing the load profile, optimizing preventive maintenance scheduling, and postponing the necessity for facility upgrades. DSM also facilitates the integration of renewable energy sources and enhances power system flexibility [83,84].

Applying the DSM activities can take the form of voluntary subscription programs. However, the limited awareness of residential customers about DSM programs resulted in relatively low engagement. In this context, AlSkaif et al. [85] proposed a system architecture that integrates gamification elements into energy applications to enhance the participation of residential customers in the electricity supply market and bridge this gap.

The main applications for engaging energy users in DSM can be classified into three categories: energy efficiency, self-consumption, and DR. Table 2 presents the energy applications incorporated in various SEGs. These games primarily focus on energy conservation and optimizing electricity usage within homes.

Table 2. Overview of energy applications, social connection, personalization methods, targets, and outcomes in different projects.

References	Project Name (Acronym)	Energy Application	Energy Carrier	Scale	Social Connection	Personalization Method	Targets	Outcome
[51,52]	EnerGAware (Energy Cat)	Energy efficiency, demand response	Electricity, gas	End-user	No	Implementing an iterative process, wherein the game requirements were identified based on feedback received from potential users during a series of gameplay scenario focus groups.	Achieving significant energy consumption and emissions reduction, upgrading electric appliances (i.e., changing energy-guzzling boilers for more energy-efficient models), improving the building's thermal performance by modifying external walls, roof, and windows, and changing the behavior of the humans living in the house with energy-efficient actions such as closing the windows while the house is being heated, using the shower for a shorter time, and turning the light off when a room is unoccupied.	The electricity-saving intervention resulted in a significant energy reduction of 3.46%, in contrast to the control group's average increase in electricity consumption by 1.68%, and houses in the experimental group used less gas during the reporting period in relation to the baseline period (2.73%). As expected, this saving was even greater in the experimental subgroup (7.48%). In contrast, houses in the control group used slightly more gas during the reporting period than in the baseline period (1.15%). The intervention did not reduce the average home electricity peak demand and average power demand at the network peak period.
[45]	Gamified HMI	Energy efficiency	Electricity (cooling)	Building, community, campus	Individuals can interact with others and visualize the winning building, promoting competitions to motivate each team to reduce energy consumption.	Applying eight-core gamification drives, their associated personality traits, and game elements. Using a predeveloped database with personality traits per country, gender, and age.	Exploring the energy effects of utilizing distinct cooling settings on thermostats in classrooms. Make the students aware of the significance of effectively managing the cooling set point. Analyzing six scenarios (by increasing the cooling setpoint starting from 22 °C and increasing 0.5 °C for each research scenario, ending with 24.5 °C) to investigate the energy impacts of using various cooling values on thermostats during classes.	Changing the thermostat setpoint from 22 °C to 24.5 °C resulted in a 50% savings in energy consumption. The recommended cooling setpoint for a classroom is 22 °C or higher. Collaboration promotes social interaction, strengthens relationships, and improves skills.

Table 2. *Cont.*

References	Project Name (Acronym)	Energy Application	Energy Carrier	Scale	Social Connection	Personalization Method	Targets	Outcome
[53–55]	enCOMPASS	Energy efficiency	Electricity	End-user, building	No	The recommender system generates personalized recommendations that are adapted to the user's current context and activity based on inputs from both the sensor and consumption data. Applying the Transtheoretical Model (TTM) of behavioral change.	Long-lasting energy efficient behaviors to produce energy consumption reduction. Encouraging individuals and groups to respond in specific ways to energy conservation policies.	The preliminary findings show that residential consumers achieved a reduction in consumption, ranging from 10% to 12%, compared to the control group.
[56–58]	Powersaver Game	Energy efficiency	Electricity, gas	End-user	No	Customized avatars	Influence household energy consumption.	After the intervention, the test group exhibited a 21.4% reduction in energy consumption compared to their pre-intervention usage. In contrast, the control group showed a 12.2% increase in energy consumption. The mean knowledge score increased from 4.27 to 5.8 points. There was no significant difference observed in engagement levels.
[24]	We Energy Game	Energy supply	Electricity	City/town	Users work together to design a town with a sustainable energy supply, ensuring adequate production, meeting the needs of people, the planet, financial viability, and maintaining a well-balanced energy supply.	No	Creating awareness about the difficulties of supplying renewable energy to a town or city by aiming for the creation of an ideal sustainable energy mix in a simulation game. Examining communicational and educational aspects of the game. Revealing the players' perspective following their gameplay experience.	The game was both enjoyable and educational for players. They enjoyed making decisions and working collaboratively. Almost all of the students reported feeling more knowledgeable and conscious about the energy transition. The game helped students explore the challenges of providing affordable renewable energy to a whole town or city.

Table 2. *Cont.*

References	Project Name (Acronym)	Energy Application	Energy Carrier	Scale	Social Connection	Personalization Method	Targets	Outcome
[59]	EnergyElastics	Energy efficiency Demand response	Electricity	End-user	Users can create a social network and invite their friends to join their social network.	Implementing a feedback system in which the adoption of energy-saving advice by each user is monitored and reflected in the application.	Motivating users intrinsically to reduce energy consumption that can lead to long-term engagement. Incentivizing behavioral changes by implementing energy pricing strategies and analyzing the disparity in carbon dioxide emissions resulting from energy usage during peak versus non-peak hours.	N/A
[60]	HotCity	Energy efficiency (identifying waste heat sources)	Heating	End-user	No	No	Providing users with the ability to spatially report and evaluate sources of waste heat in the city. Visualizing the potential sources of waste heat that were reported through an interactive process assessing the economic viability of utilizing these waste heat sources.	The 31 users identified approximately 230 spots with waste heat potential. The developed tool appears to be an excellent starting point for experts to filter the most promising waste heat locations and estimate their potential.
[61–63]	Social Mpower	Energy efficiency Demand response	Electricity	End-user	Players can communicate with each other through a chat feature accessible on the game interface.	The game is designed with a feature named "build" in which the players can personalize their house environment and customizable avatars.	Enabling participants to observe weather changes and understand the use of renewable energy. Social networking empowers users to create collective awareness and collective action in decentralized community energy systems.	The rate of successful collective action increases in tandem with the rise in the number of features aimed at enhancing collective attention.

Table 2. *Cont.*

References	Project Name (Acronym)	Energy Application	Energy Carrier	Scale	Social Connection	Personalization Method	Targets	Outcome
[64]	Energy Piggy Bank	Energy efficiency	Electricity	End-user	No	Categorizing users in the game using the Bartle Player Type Taxonomy [86].	Decreasing household energy consumption by facilitating and encouraging users to adopt new energy-saving habits (28 activities were included in the game).	Among the 39 engineering students who participated in the game, their level of interest in performing the activities varied. The breakdown is as follows: For three activities, including turning off lights when leaving a room, disconnecting chargers when not in use, and using a lid when boiling water, over 50% of the participants expressed interest in performing these activities. For seven activities, approximately 40% to 50% of the participants indicated their interest in performing them. Around 30% to 40% of the participants expressed interest in eight activities. Lastly, for ten activities, less than 30% of the participants showed interest in performing them.
[65]	Power House	Energy efficiency	Electricity	End-user	Players have the option to observe their virtual neighborhood, where they can see the virtual houses and achievements of their friends within their social network.	Customized avatars	Connecting smart meters to a gaming platform grounded in real-world social networks, allowing players to track their energy use.	N/A

Table 2. *Cont.*

References	Project Name (Acronym)	Energy Application	Energy Carrier	Scale	Social Connection	Personalization Method	Targets	Outcome
[50]	EnergyLife	Energy efficiency	Electricity	End-user	No	The application customizes the tips provided based on the consumption data collected by the sensors.	Increasing consumers' awareness about energy conservation and providing consumption feedback through long-term engagement strategies.	Users found the application useful for managing electricity consumption, increasing awareness, and changing consumption habits. Users became aware of the consequences of seemingly insignificant habits, such as leaving devices on standby or using the TV as background noise. The game motivated users to actively pursue better habits and observe the effects of their actions. Users developed a routine of regularly checking for updated quizzes and tips and actively engaging with the application to stay informed.
[47]	Smarter household	Energy efficiency (energy use habits)	Electricity Gas	End-user	No	Personalized feedback based on the energy consumption of each user.	Enhancing householders' awareness of their energy consumption patterns. Analyzing the relationship between daily routines, behaviors, appliances energy consumption, and indoor environmental conditions.	Daily actions and choices have a direct impact on our electricity consumption. Activities such as cooking, cleaning, and personal care can influence the condition of our indoor environment. Temperature, humidity, and air quality are affected by these daily activities. Imbalances in these factors can result in discomfort and negative health consequences.

Table 2. *Cont.*

References	Project Name (Acronym)	Energy Application	Energy Carrier	Scale	Social Connection	Personalization Method	Targets	Outcome
[66]	Social Power	Energy efficiency (50 electricity-saving related challenges), energy efficiency of appliances, and load shifting	Electricity	End-user	Yes (collaboration and competition)	Personalized feedback	Encouraging social interaction (collaboration and competition) and fostering behavioral changes to promote household-level electricity conservation.	The collaborative game approach resulted in higher energy savings, with an average of 42.2 kWh, compared to the control group, where energy usage increased during the game period. The competitive game also led to significant energy savings, with an average of 28 kWh, compared to the control group. Neither of the competitive teams reached the 10% electricity savings target. There was no significant difference in electricity savings between the collaborative and competitive groups. Low community cohesion was observed within the game, despite its intended focus on promoting community engagement.

A popular technique employed in these games is the use of quizzes, which effectively raise awareness about energy-related topics. However, it is crucial to consider the limitations of quizzes when it comes to facilitating deeper learning. Quizzes primarily activate low-level learning capabilities, corresponding to the lower tiers of Bloom's taxonomy [87]. These lower-level cognitive skills involve memorizing and replicating isolated pieces of information.

Electricity is the most investigated energy carrier in the reviewed studies, as indicated by Table 2, though there is a growing interest in exploring the combination of different fuel types to maximize energy efficiency. This includes the integration of electricity and gas, among others. Despite this growing interest, none of the reviewed studies provided feedback specifically aimed at optimizing the energy mix.

In the following subsection, the implementation of energy applications in serious games is discussed.

2.2.1. Energy Efficiency

Over the past years, the industry's sustained and productive effort to improve energy efficiency resulted in manufacturing devices and appliances that significantly reduce energy needs. Despite these efforts, the impact of the Jevons paradox energy consumption is more likely to increase rather than decrease as a result of economically justified enhancements in energy efficiency [88], or the rebound effect reduced the expected gains from new technologies [89,90]. This suggests that advancements in energy efficiency technologies, while promising, are inadequate in isolation and may not be sufficient to reduce personal and collective energy consumption without concurrent changes in consumption patterns.

Gamification are also widely applied in a more simple way to impact efficient energy appliance use. In these types of games, simple tricks and practices are employed to motivate energy users to engage in energy-saving behaviors such as turning off lights, reducing the use of power-intensive appliances, and closing windows [57].

The increase in energy efficiency was a prominent aspect observed across a wide range of SEG studied. In research aiming for energy efficiency activities in the game, the objective is to engage users with energy-saving tasks. As users progress in the game, they encounter new energy-saving activities and challenges in the game and their daily lives, depending on whether the game incorporates real data. The challenges considered here mostly include informative texts and tips, quizzes (such as multiple-choice questions), and photo uploads. These challenges are designed to provide information, test users' knowledge, and encourage active participation in energy-saving behaviors within the game environment.

Recent studies utilized SEG to investigate occupants' preferences within smart building infrastructures [47,53]. These games aim to encourage users to lower their energy consumption by considering various factors, such as thermal comfort, indoor air quality, lighting comfort, and general satisfaction. By incorporating occupant preferences, SEGs provide a platform for understanding the complex dynamics between energy efficiency and occupant comfort while balancing the two.

Additionally, SEGs often emphasize the use of more efficient appliances. Players are encouraged to select energy-efficient appliances and devices within the game environment or in real life, which promotes the adoption of energy-saving technologies. This approach emphasizes purchase behavior and often offers comparative analyses between the energy usage of users' appliances and the nominal average demand value for such appliances. The primary objective of these games is to promote the benefits of replacing energy-intensive appliances with more efficient alternatives, thereby encouraging energy-saving practices [85].

Another approach to enhancing awareness of energy consumption among appliances is by providing disaggregated information at either the appliance level, using smart plugs, or at the room level [91]. Identifying appliances that consume a significant amount of energy allows one to consider replacing them with more energy-efficient alternatives or adopting strategies to reduce their usage [77].

In many studies, smart thermostats were utilized to gather raw data concerning the heating or cooling demand within buildings. Heating, ventilation, and air conditioning

(HVAC) systems play an important role in providing thermal comfort by regulating indoor temperature. To address building insulation, some research focused on assessing the HVAC systems' energy efficiency by comparing energy consumption against average values [44]. However, this approach fails to address the intricate relationship between HVAC systems and building insulation. Evaluating buildings' insulation as a means of energy conservation presents a multifaceted and intricate challenge. Its complexity stems from the requirement of comprehensive assessments and interventions that extend beyond the simple replacement of appliances, making it a critical focus area for energy-saving initiatives and SEG.

2.2.2. Photovoltaic Self-Consumption

Self-consumption of photovoltaic (PV) energy entails using the electricity generated from photovoltaic systems by the power producer, contracted associates, or private household systems without injecting it into the grid. Given that PV technology is the leading contributor to distributed power generation, it presents a significant opportunity for promoting self-consumption practices [92,93]. In combination with local storage, system owners may optimize revenues by participating in energy markets, typically via aggregators.

A significant obstacle to achieving self-consumption in households is the mismatch between PV power generation and actual demand. Since a considerable portion of power production occurs when residents are away from home for work or other daily activities, the estimated potential for self-consumption without storage or DR measures ranges from 17% to 44%, depending on factors such as household size and exposure to irradiation [94]. PV electricity production follows the sun's course during the day, typically resulting in lower feed-in of PV power during morning and evening hours. However, demand peaks tend to occur during these times, creating a disparity between high demand and low PV power feed-in. Optimizing PV system capacity with the demand as a constraint leads to placing half of the system facing East and the other half facing West [95].

PV technology faces challenges competing with wholesale electricity prices. Still, self-consumption is gaining traction since the decreasing costs of PV generation are approaching or reaching parity with retail prices.

SEG can play a significant role in encouraging users to install solar panels and addressing disparities in PV generation and demand profiles, and increasing the share of self-consumption. These games can enhance customers' knowledge about the importance of self-consumption, provide incentives, and empower them with self-control to increase their participation in self-consumption practices [85].

In a study by Rai and Beck [96], it was found that serious games can effectively bridge the information gap and empower citizens to overcome informational and perceptual barriers, facilitating the widespread adoption of solar energy in residential settings. In this context, Papaioannou et al. [97] designed an IoT-based framework for decreasing energy waste in public buildings. The architecture also includes a solar power microgeneration forecast based on weather predictions and historical weather data. This feature aids in minimizing the daily energy load of the building by prompting players to time-shift energy-consuming actions to periods when the net energy balance (microgeneration minus consumption) is maximized, particularly in scenarios where energy storage is unavailable.

Some studies worked on the use of gamification related to the panels' installation (e.g., Ouariachi et al. [24] developed a game in which the users learn how solar panels can be effectively placed on farmlands, or Olszewski et al. [98], presented a social gamification platform for stimulating the photovoltaic panels' installation) and technical issues (e.g., Salim et al. [99] developed a serious game for improving the understanding and stakeholders' decision-making ability for end of life management of PV panels).

2.2.3. Demand Response

The stability of energy grids depends on the continuous balancing of energy supply and demand. The integration of intermittent renewable energies, such as wind and solar, which are heavily influenced by factors such as weather, makes the task of balancing the energy grid increasingly challenging [100]. In this regard, an important challenge is educating individuals about the complexities of balancing supply and demand in different locations and conveying that larger locations present unique complexities [24]. It is essential to emphasize how individuals can actively contribute to the balancing process by aggregating distributed resources. Individuals can collectively form virtual power plants by pooling together smaller-scale renewable energy sources and DR capabilities. These aggregated resources can then be integrated into the grid to assist in balancing the fluctuations of intermittent renewable energies.

Accordingly, policymakers and market participants recognize the significance of demand-side flexibility, particularly through DR mechanisms, to address these challenges and efficient electricity systems. In this context, intermediaries, such as suppliers and aggregators, offer DR programs to retail customers in the energy market through voluntary participation. These programs involve a contractual agreement outlining legal and technical criteria for implementing and verifying DR and incentives to encourage customer participation [15].

Generally, DR programs are classified into incentive-based and price-based categories [101]. To promote DR programs among consumers, various strategies are employed, such as time-of-use pricing, critical peak pricing, variable peak pricing, real-time pricing, and offering critical peak rebates. Additionally, power companies implement direct load control programs to regulate energy usage by cycling appliances such as air conditioners and water heaters during peak demand periods [85].

One incentive for using gamification for promoting DR programs is explained by Konstantakopoulos et al. [102]. Implementing DR programs is typically based on contractual agreements between utility providers and consumers. However, these contracts lack the flexibility to accommodate dynamic changes in occupant behavior and preferences, leading to discrepancies in demand expectations. To address this problem, they developed an approach that incorporates a gamification interface that enables building managers to interact with occupants and allows retailers and utility companies to utilize dynamic and temporal data to customize DR programs based on observed or predicted conditions. This approach enhances the adoption of more dynamic protocols for DR [103].

From the reviewed papers, only three applications concerned DR in their games: EnerGAware (Energy Cat) [51,52], EnergyElastics [59], and Social Mpower [63]. In the Social Mpower application, the researchers incorporated load shifting as a strategy in addition to energy-saving tips and quizzes. Users were encouraged to shift their electricity loads from periods of high demand to off-peak periods. This involved tasks such as running the dishwasher, oven, washing machine, or tumble dryer during times when overall electricity demand is lower.

The scarcity of DR-related games can be attributed to several factors, including fixed energy costs, the lack of information regarding off-peak periods, and the absence of incentives to highlight the potential impact of shifting energy usage. As a result, serious games in this domain are less popular than those centered around energy conservation [104].

Lampropoulos et al. [15] identified five objectives for the integration of gamification techniques in DR applications:

- Educating users about commercial offerings, including DR programs and self-consumption schemes.
- Raising awareness about energy usage through advanced metering infrastructure and consumer interfaces.
- Driving adoption of smart grid technologies and smart appliances.
- Encouraging active participation in DR programs and self-consumption schemes through incentives.
- Influencing behavioral changes measured by key performance indicators.

In a study by Gnauk et al. [100], gamification is used for demand dispatch. The demand dispatch system aims to encourage consumers to meet their energy demand with flexible options and maintain their engagement over the long term. They used gamification to develop an intrinsic motivational framework for consumers to explore their consumption habits enjoyably and interestingly, establishing a deep commitment to the program. The demand flexibility system proposed in this study consists of three steps: submission of new flexibility by the customer in the definition phase, utility-side review through multiple rescheduling runs, and ultimately reaching the dispatch phase. After evaluating this approach, users exhibited increased motivation and incentive to actively participate in the program.

2.3. Social Connection

The inclusion of social connections in SEG can enhance the enjoyment and attractiveness of energy applications. This social dimension not only adds an element of fun but also creates a sense of community and encourages positive energy behaviors [85].

Incorporating social elements and online interactions into gamification approaches can harness the significant potential of social connection to elevate energy-related experiences. This integration holds promise for fostering positive energy behaviors, promoting knowledge sharing, and facilitating collective problem solving, ultimately contributing to enhanced energy experiences and improved outcomes.

Recent literature paid significant attention to the crucial role that social ties play in SEG. For instance, social ties were recognized as powerful tools for increasing player engagement and promoting behavior modification. In the PEAR project, players establish teams with friends and encourage cooperative energy-saving acts, demonstrating the influence of peer pressure and competition in encouraging sustainable habits [105]. Similar to this, the Powersaver project makes use of household-based teams, where players track and lower their household's energy use and then compare their results with other teams [106]. In today's digital learning environments, social learning is a trend that is amplified by such processes. According to Bandura's social learning theory, peer observation and utilizing social experiences can result in significant behavioral changes [107]. When players, in their neighborhood-based teams, observe peers making energy-saving decisions or implementing best practices, they are more inclined to emulate such behaviors.

The concept of collective awareness of energy use is incorporated in many SEGs and defined as an attribute found in communities or teams that help them solve collective action problems [61]. Without collective awareness, individuals may disregard community norms and fail to understand the impact of their actions. In communities with collective awareness, members take synchronized actions to achieve desirable outcomes for shared resources.

Several SEGs are designed to educate energy consumers about resource allocation, electricity prices, and grid sustainability. Some games go a step further by incorporating social connections to enhance the learning experience. One such game is Social Mpower, which aims to prevent a collective blackout. Players achieve this by individually reducing their energy consumption and coordinating their actions in synchronization with others [61–63].

Different methods are developed for users' communication in SEG with social connection elements such as in-game messaging, chat or discussion forums, and team or group communication. Alskaif et al. [85] proposed to enable users' communication by linking the application to social media or developing a private web-based or mobile-based platform.

In the Social Power project, the household participants were assigned to one of two teams: either a collaborative team where citizens in the same city try to reach a fixed, collective 10% electricity savings target together or with a competitive team that tries to save the most electricity in comparison to the other city. For social connection, the users designed a blog and Facebook page as a place for participants to interact, share experiences, and cooperate to build a creative understanding of how to save electricity at home. Players could find more detailed information about the energy-related topic of the week, post tips, offer suggestions, ask questions, and could cheer on their teammates. However, few participants were engaged in these traditional communication channels, and more interest was shown in the app challenges.

In another study, Kashani and Ozturk [59] created a gamified platform for promoting energy-saving behavior using a mobile application that users can access via their Facebook accounts. The application requests permission to access the user's friend list, allowing them to invite friends to participate in the game's challenges. Through this feature, the application facilitates the creation of a social network, enabling users to share information and engage in friendly competition. Additionally, the application presents other users' energy-saving activities, creating an educational and competitive environment that encourages individuals to learn about energy-saving solutions.

In some studies, the social connections among users of SEGs were limited to the social sharing of their achievements and challenges, typically involving users sharing their progress, scores, or energy-saving accomplishments on social media platforms, fostering a sense of competition and community engagement. However, in other studies, the focus goes beyond mere social sharing. It extends to creating an energy community, in which users actively cooperate and share resources, particularly in the context of shared renewable energy sources, e.g., a co-owned PV installation shared between the residents of the community [104].

The body of research consistently underscores the capacity of both competitive and cooperative game mechanics to promote social engagement in the context of energy-related activities.

Collaboration and Competition

The surge in online gaming and the proliferation of online connections among players paved the way for the application of collaboration within the realm of SEG. This paradigm shift involves moving away from solely focusing on individual scores and achievements and embracing the concept of collective scores. It also entails transitioning from fixed user roles to user-adaptive roles, allowing players to adapt their roles based on the specific energy challenges dynamically. By leveraging the power of collaboration, SEG can foster a collective reduction in energy consumption during peak hours, leading to significant impacts on the overall energy system [85]. However, collaboration is still one element that is missed in most SEGs [108].

"We Energy Game" [24] is an excellent example of how serious games can utilize cooperative mechanics in a simulation environment. In this game, five different roles are defined as production (project leader responsible for energy production), people (the citizens), planet (responsible for clean energy production), profit (responsible for measuring the profit made by the different projects), and balance (responsible for the network operation). To obtain a positive balance, players must work collaboratively to achieve the total score for the chosen town. To do so, they must strategically use various energy sources, each offering a point value for each role. Players place these sources on a map to accumulate points and must balance the positive and negative scores to find the optimal solution with a mix of all available sources.

To foster social influence within the system, Alskaif et al., proposed applying competition by enabling the users to compare their performance with other customers of similar household size and friends, neighbors, or the average household [85]. Normative feedback can be incorporated into collaborative game designs to showcase the collective performance of a group and promote energy-saving behaviors. Grevet et al. [109] developed a social visualization system for energy-saving behavior within a scalable society. This system allows for establishing society-wide goals and aims to encourage collective energy behavior. The social visualization provides unidimensional and multi-dimensional comparative feedback, enabling participants to compare their energy-saving efforts within their group and across different groups.

In another study by Muchnik et al. [110], the authors explored the potential for competition and collaboration within saving energy applications. As a means of fostering competition, users were able to compare their energy usage with that of their peers, including friends on social networks or the average user. To ensure that such comparisons were meaningful, the authors recommended providing filters allowing users to compare their energy usage with others in similar types of buildings or apartments. Regarding collaboration, the authors defined it as an energy-saving tip exchange whereby users could share tips and utilize tips from other users.

In many studies, the normative feedback approach is employed to nudge users to change their behavior [111]. One effective aspect of this approach is the ability to compare residents' energy usage with their peers in similar buildings, often presented through graphical representations. This comparison created social pressure among peers (peer pressure), motivating residents to embrace energy-saving practices [112–114]. The effectiveness of normative feedback is enhanced when it conveys that a significant majority of other users of the application already adopted the desired behavior [115].

In SEG, the normative feedback approach is commonly implemented through leaderboards, allowing users to compare their total energy consumption or energy-saving performance with others or the community as a whole. However, it is crucial to acknowledge that implementing the normative feedback approach without considering the necessity for personalization to establish a more precise basis for comparison can lead to ineffectiveness, as demonstrated in several research studies. For instance, in their study, Kim et al. [114] underscored the significance of considering the households' demographic characteristics and any specific underlying health conditions when considering energy consumption to ensure fairness within leaderboards.

2.4. Personalization

The idea of personalization (tailoring the gaming experience to meet the individual preferences and characteristics of each player's individual preferences and characteristics) in SEG to enhance their effectiveness and impact is receiving increasing attention in recent studies. A few of the available tools for energy conservation guidance often exhibit a generic approach, where the advice is presented in a "one size fits all" manner applicable to everyone [116].

In this context, different approaches are implemented for personalizing the game environment in both the design and implementation stages (Table 2).

Achieving this objective necessitates a comprehensive understanding of the user's needs, expectations, typology, habits, and comfort level to provide timely, relevant, and personalized feedback [54,117].

Implementing behavior change theories in a serious energy application is an approach used in some studies for personalization. Muchnik et al. identified four key behavior aspects to address when developing an energy application [110]. Firstly, the "foot-in-the-door" technique should be used to show users that they already care about energy conservation. Secondly, users should be involved in competitions; however, it is important to consider the unexpected influence of the "boomerang effect" on low-energy consumers [118]. Thirdly, the application should provide users with feedback on their successes and failures. Lastly, information should be presented in an easy-to-understand manner.

Several theories and models regarding human behavior were developed to affect meaningful changes in users' habits. Mendez et al. [119] identified three of them to reduce household energy consumption. The first, TTM [120] classifies the process of behavior change into six stages, including pre-contemplation, contemplation, preparation, action, maintenance, and termination. The model was utilized across multiple domains to encourage behavior change, including promoting water [121] and energy conservation [122] among residential customers.

Alskaif et al. [85] defined the requirements for energy-related behavior change and implementation of energy-related strategies in various stages based on the 5-stage TTM model, as depicted in Figure 1. These strategies include the knowledge process, learning how to use and interact with a platform for promoting energy applications, adopting new energy consumption behaviors, observing the outcome of the user's actions, and providing incentives to sustain the new energy consumption behavior.

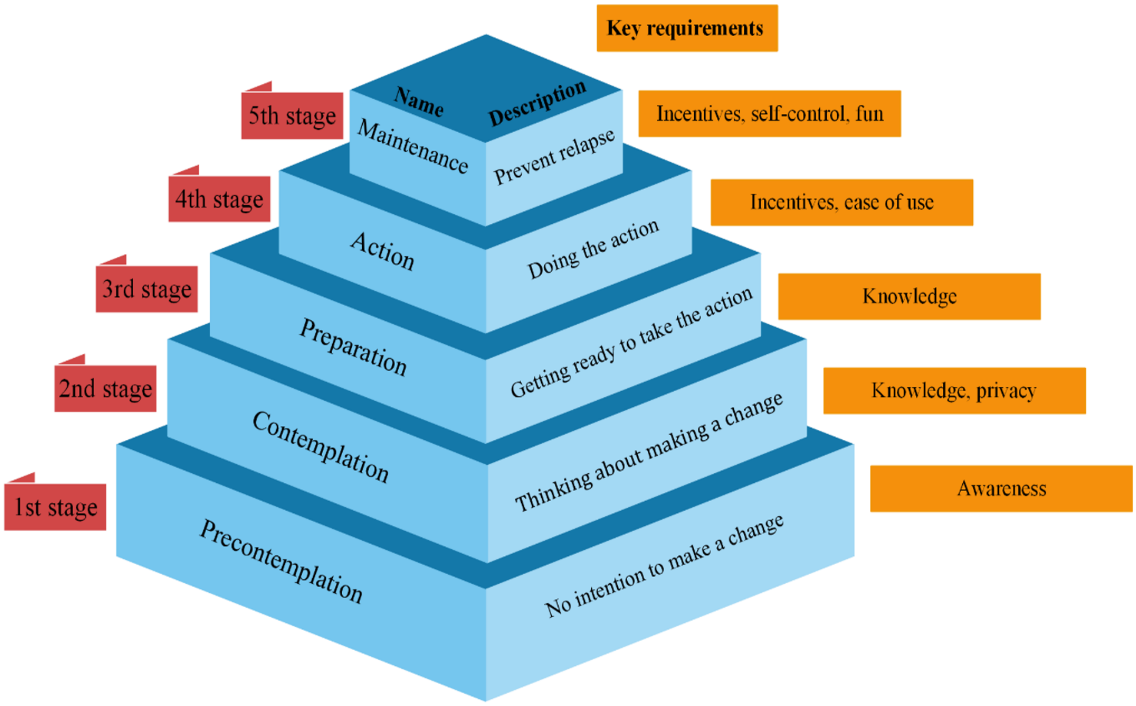

Figure 1. Energy-related behavior change requirements based on the TTM model [120].

The second model, the Fogg model [123], emphasizes the convergence of motivation, ability, and prompt elements as necessary conditions for behavioral change. Based on this approach, Wendel suggested an iterative cycle for behavior change based on four steps: gaining insights into strategies for modifying behavior, establishing target users, desired actions, and intended results, creating a user interface that aligns with user scenarios, and evaluating outcomes and enhancing the product based on feedback [115]. Based on Wendel's proposal, Kim et al. [114] developed an eco-feedback design to promote energy-conserving thermostat adjustment behaviors. The four steps outlined above were implemented as follows: reviewing eco-feedback strategies that were utilized by previous research, reviewing existing literature on residents' behaviors regarding programmable thermostats to identify the target behaviors, creating an interface that aligns with users' primary tasks and behavior scenarios, and developing a test and refinement approach to enhance the overall user experience.

The third model, the theory of planned behavior [124], posits that an individual's behavioral intentions are shaped by three key factors: attitude, subjective norms, and perceived behavioral control. Based on the theory of planned behavior, Mendez et al. [119] proposed an energy-saving behavior model for smart homes combined with gamification elements.

In a few studies, users engaged in the application development process through co-creation and co-design sessions. This helps researchers to gain insights into users' needs, preferences, and goals. For example, the EnerGAware project invited social tenants to develop its application. Initially, the project team collected the users' ideas and inputs related to the initial game concepts. The same group was then utilized to test early game prototype ideas. Finally, the group was employed as the pilot for the deployment and testing of the application [54]. While the co-design and co-creation approach showed promise in various contexts, its application in developing SEG is still a work in progress, particularly due to the intricate nature of the development process for digital games.

In addition to various approaches for delivering personalized feedback to users, another effective method involves providing personalized information on demand. One such method is the ability to forecast future energy consumption, enabling users to anticipate their energy needs and make informed decisions accordingly. Another aspect involves clustering users based on their energy consumption profile, allowing them to be categorized into groups with similar energy usage patterns. This clustering helps identify user segments and tailor feedback strategies accordingly [125]. Moreover, this method provides disaggregated data on individual users by breaking down energy usage by specific appliances, time periods, or activities.

One study that stands out for its robust methodology in the area of energy consumption personalization was conducted by Fraternali et al. [53]. The authors utilized different data collection sensors, such as smart plugs and smart meters, to determine the activities of energy consumers, including sleeping, cooking, and resting. They also measured the comfort level and energy behavior of buildings and stored the extracted values in a database with a reference timestamp for use by the recommendation engine and other components of the application [53,54]. An adaptive in-context action recommendation feature was developed in their framework that computes actionable energy-saving suggestions. The recommender clusters users into categories and utilizes their activity patterns to generate energy-saving recommendations specific to their context. Furthermore, it prioritizes energy-saving recommendations based on the user's context, activity, and suggested action's potential impact. To overcome the cold start problem, the recommender is equipped with general rules that apply to all classes of users and buildings and are used to initialize the feedback loop between the recommender and the user.

Changing energy behavior can potentially negatively impact the quality of life, as individuals may have different priorities to consider [45]. In this regard, Fraternali et al. [53] classified the comfort level of the users into two categories: visual and thermal comfort. Visual comfort is determined by the human perception of luminance within a building and is assessed using the Kruithof graph, as described by Fotios [126]. Meanwhile, thermal comfort is determined by the human perception of indoor temperature and is evaluated using the predicted mean vote index, as outlined by Cigler et al. [127]. As the users progressed in the application, the researchers observed changes in their comfort level.

According to Csikszentmihalyi's concept of "flow", optimal experience and engagement occur when the challenges of an activity match the users' skills [128]. Translating this into the SEG context, the concept of flow could ensure that the challenge levels correspond to the user's skills, promoting their active engagement and sustained interest in the game (see Figure 2). For instance, if the game's energy-saving challenges are too easy for experienced users, they may lose interest due to boredom. Conversely, if the tasks are too difficult for novice users, they may become frustrated and disengage. Implementing a dynamic system that tailors the level of challenges to the players' skill levels may optimize user engagement. As such, the game can effectively guide the user towards sustainable energy behaviors while keeping them motivated [129].

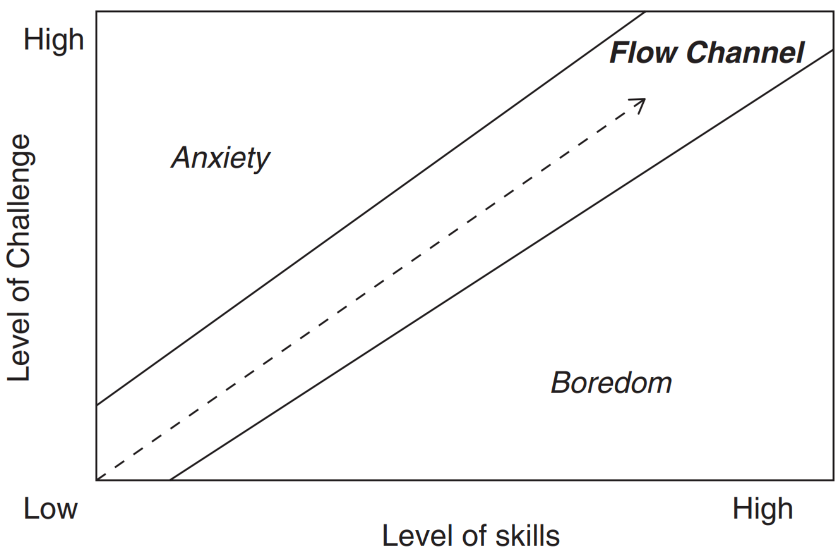

Figure 2. Illustration of the "Flow" theory (optimal playstate) by Csikszentmihalyi [128].

The "flow" can be maintained by dividing it into four main categories: engagement, learning outcomes, usability, and user experience.

- Engagement: If the difficulty of a serious game is balanced with the users' abilities, they are more likely to remain engaged. When the game is too easy, it can result in boredom, and the users may lose interest. On the other hand, if the game is too hard, it can lead to anxiety and frustration, which also decreases engagement.
- Learning outcomes: The level of challenges directly influences the learning outcomes. An optimal difficulty level in a game encourages deep learning and fosters intrinsic motivation. It creates a more rewarding experience for the users, increasing the chances of returning to the game and absorbing more knowledge about energy management and savings.
- Usability: Balancing game difficulty can also enhance the usability of a serious game. If the users perceive a game to be within their skill level, they are more likely to understand and utilize the game mechanics. This perception of competency enhances the user experience and makes the game more accessible and enjoyable [130].
- User experience: Overall, ensuring the right level of difficulty contributes to a positive user experience. A game that is appropriately challenging enhances satisfaction, promotes longer play times, and can increase the desire to play again. All of this contributes to a more enjoyable and effective serious game. By ensuring that "flow" (optimal play state) is achieved, a significant contribution can be made towards mitigating user participant attrition and fostering sustained long-term engagement in the game.

Categorization of users is a widely used strategy for providing personalized feedback in SEG. In Table 3, different categorization techniques that were implemented in previous studies in this field are described.

The Bartle player type taxonomy [86] proposed the classification of players into four categories, each characterized by distinct propensities and motivations. Hedin et al. [64] designed the Piggy Bank game for energy saving based on this categorization to make the game appealing to all player types. While the developed game in this study considers various player types, it is concluded that individuals classified as "Achievers" may exhibit superior performance and greater enjoyment when engaging with this application.

Frankel et al. [131] presented five categories of market segments and the main characteristics of energy customers. They presented this framework to assess how providers can deliver energy efficiency opportunities to the market. Ponce et al. [132] applied this classification to design an intelligent expectation interface for adopting smart thermostats, and Mendez et al. [119] applied the same approach using a gamification structure.

In another classification by Peham et al. [133], energy target groups are divided into three categories: early adopter, cost-oriented, and energy-conscious.

Some studies utilized personality traits as a categorization technique, which has proven effective in delivering personalized feedback in SEG. Among the various categorization approaches, the big five personality traits emerged as the most frequently employed method.

Personalization plays a crucial role in elevating the effectiveness and impact of SEG. Incorporating behavior change theories, co-design and co-creation sessions with potential users, and personalized feedback strategies contribute to a comprehensive and user-centric approach. Categorization techniques, such as player types, market segments, and personality traits, further enhance personalization, allowing for tailored experiences that resonate with specific user groups. The emphasis on user comfort levels and the consideration of diverse priorities ensure that energy-related activities align with users' needs and does not compromise their quality of life.

Table 3. Categorization for personalization based on the application users' types.

Categorizations	References	Types	Description
Player type [86]	[64,134–137]	Achievers	This group of players prioritizes the accumulation of points and the advancement through levels as their primary objective in the game. Their focus lies in achieving tangible progress and measurable success.
		Explorers	Explorers are driven by a deep curiosity to unravel and comprehend the intricate mechanics underlying the game. The true enjoyment for them arises from the discovery process, as they strive to uncover hidden aspects and delve into the game's intricacies.
		Socializers	Socializers place a high emphasis on social interaction and forming connections with other players. They view the game as a platform that facilitates social engagement and serves as a shared space where meaningful interactions and experiences occur.
		Killers	The killer archetype finds pleasure in dominating and controlling others within the game. They derive satisfaction from creating disruptions and causing distress to fellow players. The extent of their enjoyment often correlates with the magnitude of chaos they can generate within the game environment.
Energy end-user segments [132]	[119,132,137,138]	Green advocate	The most positive overall energy savings, strongest positive environmental sentiments, and interest in new technologies.
		Traditionalist cost-focused	Extensive overall energy-saving behavior motivated by cost savings, limited interest in new technologies or new service programs.
		Home focused	Concerned about saving energy, more interested in home improvement efforts, and driven by an interest in new technologies and cost savings.
		Non-green selective	Selective energy savings behavior with a focus on set-and-forget inventions, not concerned about environmental considerations.
		Disengaged	Less motivated by saving money through energy savings, not concerned about environmental considerations, not interested in new technologies.
Personality traits	[119,137,139,140]	Openness	These individuals appreciate divergent thinking. They have new social, ethical, and political ideas, behaviors, and values.
		Conscientiousness	They are self-disciplined, competitive, dutiful, and responsible. They have a rational, purposeful, strong-willed attitude.
		Extraversion	They are energized by social interactions and exciting and diverse activities.
		Agreeableness	These individuals are altruistic, modest, and have a cooperative nature. They have a sympathetic and tolerant attitude to others.
		Neuroticism	Tend to experience negative emotions such as fear and sadness.
Energy target groups [133]	[119,139–141]	Early adopter	Enthusiastic about new technologies, actively participates in online social communities, and lacks awareness or interest in energy conservation.
		Cost-oriented	Focus on cost-oriented behaviors and try to adopt a sustainable lifestyle.
		Energy-conscious	Attempt to lead a sustainable lifestyle and be energy-aware.

3. Data Integration

Data integration from diverse sources empowers SEGs to offer personalized experiences, targeted interventions, and actionable insights to the players. Combining disparate data streams, such as historical and (near) real-time energy consumption information, efficiency levels of various appliances and devices, grid information, renewable energy generation, demographic and socioeconomic data, user behavior data (e.g., gameplay interactions, progress, and choices), user perceptions and attitudes, engagement of users in gamification elements, social interaction of users, and feedback and survey data, SEGs can empower users to make informed decisions and take actions towards sustainable energy practices. Data integration in SEG can also involve external data sources such as weather data, geographical information, and energy market prices.

Table 4 provides an overview of the user participation in the research, the data collection tools, the measured variables, and the analysis methods.

The successful participation of users is crucial when evaluating the effectiveness of energy applications. The provided table outlines key details, including the sample size and the recruitment methods employed to ensure diversity and representativeness of the user population. However, some studies raised concerns about households' willingness to invest their time and resources in these applications [110]. To address this challenge, it is essential to create a user-friendly experience with a streamlined registration process and free access to the application. Additionally, incorporating gameplay elements that encourage meaningful social interactions, such as sharing energy-saving tips with neighbors or competing with other neighborhoods, can significantly enhance users' engagement and willingness to participate in the application.

3.1. Data Collection and Analysis

The lack of established data collection tools posed a significant hurdle during the initial development phase of serious energy and environmental games, such as PowerHouse [41] and EcoIsland [142]. As a result, the reliance on self-reporting and aggregated measures emerged as the primary means of gathering data for these games. This practical approach allowed researchers to assess the impact of these games, although it was limited by the lack of sophisticated data collection methods. Incorporating advanced data collection tools could enhance the accuracy and reliability of data collection in similar gaming contexts, such as EnergyLife [50].

Accurate energy demand simulation requires detailed information. The quality of simulation results depends on the quantity and quality of input data. Therefore, collecting and analyzing data from various sources and at different levels is crucial to ensure that the simulation is as precise and reliable as possible [110]. Wemyss et al. [66] identified a challenge in data collection related to energy consumption. They noted that gaps in the data occurred due to technical issues with data transmission. In some instances, the transmission of hourly data was unpredictably delayed or not received at all in the application server. As a result, incorrect calculations of energy savings were made. To address this issue, it is crucial to implement corrective measures, such as conducting data resets with accurate information and data imputation, to ensure the reliability and accuracy of the calculations in such cases.

Zeile et al. [60] created a serious game to produce specific incentive systems for data collection. The game draws inspiration from the "Pokemon GO" game, allowing users to report and evaluate the spatial potential of waste heat in the city. The developed application can also streamline data collection from small energy sources typically excluded in top-down methodologies.

Table 4. Overview of data integration and performance assessment in different projects.

References	Project Name (Acronym)	Participation of Users	Data Collection Tools	Measured Variables	Data Collection Method and Data Analysis	Performance Assessment
[51,52]	EnerGAware (Energy Cat)	The social housing survey was sent by post to 2772 social houses; 137 confirmed they wanted to take part in the monitoring stage, from which 88 monitoring systems were deployed; half of them were in the experimental group and half in the control group. Reminders were sent out to encourage households to complete and return the survey.	Energy metering sensors, an optical pulse reader, and a standard wireless M-Bus pulse counter were attached to the existing electricity meters. A data concentrator collected monitoring data and periodically sent it to a remote data server.	Energy consumption, energy consumption behavior and energy awareness, peak demand, social media activity and energy knowledge sharing, IT literacy, socio-economic status and health, energy price, perceived physical comfort, usability and usefulness, and game interaction.	Pilot households' gaming experience data, available from the game server. Energy consumption data were collected by the energy monitoring system installed in the pilot homes. Local weather data, available from an automatic web weather service, was used to analyze the weather impact on the energy consumption profile. A baseline survey to all pilot homes asking about energy consumption behavior, energy awareness, IT literacy, and self-reported manual meter readings to cross-check automatic readings.	The energy consumed by a house in one week is compared to the energy consumed the same week the year before. Three months after the implementation of the game, the same survey was sent again to all pilot homes, with questions to collect feedback on the game from houses in the experimental group. Face-to-face interviews were held with the tenants to gather detailed feedback on the game.
[45]	Gamified HMI	N/A	Thermostats located on the university campus.	Weather data, construction materials of buildings, classroom schedule and loads, setpoint and setback for cooling and heating, building location and orientation, and personality traits.	From the user's interaction with the interface, their game feature preferences and personality traits are determined, the thermostat setpoints data are collected to be used in a two-layer feed-forward artificial neural network decision-making system, which was modeled to predict the electricity requirement for cooling each building.	Energy consumption is compared before and after adjusting the thermostat setpoint.
[53–55]	enCOMPASS	The enCOMPASS platform was implemented in three pilot sites in Switzerland, Germany, and Greece, with approximately 100 participating households in each pilot. Additionally, each pilot includes at least one public building and one school.	Electricity meters, sensors installed at the user's premises, and user's actions on the gamified application.	Energy consumption from smart electricity meters and smart plugs at the individual appliance level. Sensor data, including the presence, temperature, luminance, and humidity at the user's premises. Psychographic variables from mobile apps (e.g., household composition and existing appliances) and results of instant polls (e.g., quick feedback on comfort conditions).	The sensor data stream is exploited by an activity tracker subsystem, which infers the current activity of the user in the building; the consumption data stream is exploited by a disaggregator, which estimates the partition of the total metered consumption into end uses (e.g., water heating, specific appliances, etc.). Algorithms for extracting activity data from sensor measurements and app data, profiling different types of user behavior, inferring activity context, and predicting reactions to stimuli (e.g., energy-saving tips).	Comparing the changes in energy consumption with the control group.

Table 4. *Cont.*

References	Project Name (Acronym)	Participation of Users	Data Collection Tools	Measured Variables	Data Collection Method and Data Analysis	Performance Assessment
[24]	We Energy Game	A group conversation was arranged for 15 students, ranging in age from 21 to 33. The researchers presented the game to the students and then assigned them to play in groups of five for 40 min. After the game's completion, the students engaged in a 15-min group discussion.	Survey.	Users' attitude towards their engagement in the game, interest in learning more about energy transition, and willingness to their energy-saving behavior.	N/A	After playing the game, the users' attitudes were examined through a survey.
[59]	EnergyElastics	N/A	Smart meter, mobile application.	Energy consumption, application use data.	Saved energy within a specific time, users' reaction to energy-saving feedback, CO_2 production, information on the performance of each user's social network.	N/A
[60]	HotCity	N/A	Mobile application, survey.	Waste heat sources in the city. Usability and acceptance of the app. The functionality of the app for identifying waste heat sources. Participant location using GPS data.	After a 2–3 week test phase, an online survey was administered to all participants to collect feedback on their experience using the application. The waste heat experts reviewed the images and input data submitted by the testers in the application to verify the waste heat potential.	The participants were asked to complete a questionnaire to provide feedback on various aspects of the application, such as its usability, security features, integration of game elements, and overall structure. Waste heat experts evaluated the participants' performance to ensure correctly classified waste heat sources based on the tutorial and GPS position.

Table 4. *Cont.*

References	Project Name (Acronym)	Participation of Users	Data Collection Tools	Measured Variables	Data Collection Method and Data Analysis	Performance Assessment
[64]	Energy Piggy Bank	The study involved 39 engineering students who were required to participate in a course. One participant opted out, and five did not complete the assigned tasks, resulting in a total of 33 students who completed the study according to the prescribed requirements.	Survey, mobile application.	Type of player using the Bartle test. Activity opportunity of each user (e.g., one task in the application involved fixing a leaking toilet. However, this task was only relevant for users who had a leaking toilet in their household). Level of motivation and engagement, self-estimated behavior change, and activity performance.	Various questionnaires were utilized at different stages of the study.	After the trial period, participants were asked to complete a questionnaire to estimate their anticipated future behavioral changes. They were presented with a list of activities featured in the application.
[65]	Power House	N/A	Smart energy meter, mobile application.	Energy consumption, application use data.	The application's dashboard offers users a comprehensive view of their energy consumption (i.e., a graph for displaying the energy consumption of the last 24 h, the possibility for comparison with previous days, detailed summary of their in-game status). Chat forum for users to engage with each other by making comments or answering questions posed by the player community.	Pre- and post-test survey.

Table 4. *Cont.*

References	Project Name (Acronym)	Participation of Users	Data Collection Tools	Measured Variables	Data Collection Method and Data Analysis	Performance Assessment
[50]	EnergyLife	The study involved 24 participants (11 men, 13 women) with an average age of 34.87. Field tests were conducted in Finland and Italy, with four households per country participating. The selected households were urban dwellers owning their homes, chosen for their high saving potential and representation in both regions. None of the households included project members.	Sensors installed for specific appliances (i.e., washing machine, PC, TV, microwave, refrigerator, and two other devices of the participants' choice), survey, and visit with participants.	Real-time electricity consumption of the appliances, access to the application, and satisfaction and experience of users with the application.	Wireless sensors were used to measure the energy consumption of appliances by inserting them between the plugs and sockets. The collected data were transmitted to a base station within the house and then sent to a cloud service. The cloud service communicated with smartphones running the application,	The general acceptance and usability of the application were evaluated using a questionnaire. Player's awareness.
[47]	Smarter household	The trial comprised 19 households from different towns in the UK, representing various housing types. Most participants were categorized as low-income earners, including the unemployed and retirees. A social housing provider contacted the target group through emails and text messages. Interested households were then invited to complete an expression of interest form to participate in the research.	Smart energy meter, Sensors for monitoring the indoor condition in the lounge and kitchen areas.	Real-time energy consumption, estimated energy cost, indoor humidity, indoor temperature, and CO_2 level. Semi-structured interviews and activity diaries are being employed to collect qualitative data. Participants' engagement with the dashboard and serious game.	The unprocessed data were stored in a remote database. Following that, it undergoes a thorough cleansing, analysis, and visualization process, all to foster user awareness. The participants' daily activities (e.g., sleeping, walking, and daytime activities) were identified, and their correlation to the activities' energy consumption and indoor environmental conditions was analyzed.	N/A

Table 4. *Cont.*

References	Project Name (Acronym)	Participation of Users	Data Collection Tools	Measured Variables	Data Collection Method and Data Analysis	Performance Assessment
[66]	Social Power	The study was conducted in two cities where 120 households were initially targeted. However, 108 households participated in the experiment. Control groups were included as benchmarks, consisting of 30 households in each city selected anonymously, to compare electricity consumption during the same time period as the experimental group that received the intervention. Participants were divided into two game environments: collaboration and competition. In the collaboration game, users from the same city worked together to reach a 10% electricity-saving target. Meanwhile, the competition game involved a competition between the two cities, aiming to achieve the highest level of electricity saving.	Smart energy meter, mobile application.	Approximately real-time hourly energy consumption. Application use data.	The electricity use feedback is presented in the application's dashboard, The hourly and weekly comparison of energy consumption with historical consumption was provided for the users. The competitive interface provided a thorough comparison of savings progress, points earned, and the number of challenge activities completed between the two cities. The collaborative interface provided the individual household's savings progress concerning their team's performance and a visual representation of their proximity to milestone targets.	To establish comparable conditions, the control groups were carefully constructed using a stratified sampling approach to ensure a similar distribution of household types (such as single individuals versus families, apartments versus houses) as the participating teams. The electricity-saving progress of the participating households was analyzed by tracking their electricity consumption patterns before, during, and after the intervention period to compare the outcomes based on the specific treatment received.

The enCOMPASS [53] project stands out due to its comprehensive approach to data integration in SEG. In this project, various data collection tools were employed, including the use of smart plugs to measure the energy consumption of appliances, the aggregation of energy consumption data from smart electricity meters, and environmental sensors that measure the presence, temperature, luminance, and humidity, among other parameters. In addition, the project leverages psychographic variables obtained from the mobile app's user profile information and instant polls measuring user activity or comfort conditions. To provide energy-saving recommendations to users, enCOMPASS implemented a technical architecture consisting of several interconnecting components, including sensor and user data acquisition, data analysis and user modeling, engagement engine with adaptive gamification, application programming interfaces, behavioral change application, and energy efficiency assessment console.

The data collected in most studies combined quantitative and qualitative methods. The questionnaire was the most widely used data collection tool, primarily employed to assess the increase in knowledge of energy saving and evaluate the effectiveness of SEG in engaging users. The questionnaires were administered in various ways, including paper-based surveys, online surveys, and in-person interviews, with the option of voice or video recording the interviews for future analysis, subject to the participant's agreement. In pre-post evaluations, the questionnaires were utilized to measure changes in participants' knowledge and attitudes regarding energy saving before and after their engagement with SEG.

With the growth of smart technologies, new data collection tools were developed to gather data from SEG more efficiently. Smart energy meters and smart thermostats are among the most common tools discussed in the following subsections [53].

3.1.1. Smart Meters

Achieving the transition of conventional electricity grids to smart grids, which facilitate the bidirectional flow of electricity and information from power generation units to all points along the grid until delivery, is essential for the integration of renewable energy sources, management of energy demand, and improving reliability and security of the grid [143]. Smart metering plays a critical role in the transition to smart grids by serving as a fundamental basis for monitoring the grid load's performance and energy utilization characteristics, making it an essential component of the transition process. Thereby, policy and regulatory initiatives emphasized the need for the deployment of smart metering. For instance, the EU Recommendation 2012/148/EU for reaching 80% implementation by 2020 insists on minimum functional requirements of this infrastructure and active participation of individual customers in the planning and use of electricity [144].

A smart meter is a digital electric meter that measures and keeps a record of the electricity consumption in real time, including calculation hardware, software, calibration, and two-way communication capabilities between the utility and the customer for monitoring and billing processes [145].

The rollout of smart metering systems in various countries in recent years has presented an opportunity to implement feedback systems. These systems leverage the capabilities of smart meters to provide users with detailed information and insights regarding their energy consumption patterns [146]. Smart meters played a central role as the primary data collection tool for developing SEG. With the assumption that smart meters will be installed in every household in the future, these meters hold immense potential for scaling up the proposed platforms. This scalability opens up opportunities to engage a broader audience and promote various energy applications and DR programs on a larger scale.

Recent research on smart meters highlighted their potential for supporting analyses in various areas, including a better understanding of energy use, developing data-driven models for future energy prediction, and determining the potential for peak load reduction [147]. However, nearly all reviewed studies primarily focused on the first aspect, leaving a potential research gap for further exploration of the development of advanced techniques or methodologies for utilizing smart meter data in the context of peak load reduction and optimizing energy management strategies. Smart meter data can be utilized to derive valuable insights regarding housing characteristics (e.g., socio-economic status, dwelling types, and appliances) and the clustering of buildings based on their energy consumption patterns [148,149].

3.1.2. Smart Thermostats

Smart thermostats' adoption rate is considerably lower than that of smart meters, as smart meter installations are mandated by regulations [144]. In contrast, smart thermostats are predominantly purchased by building owners or provided by utilities [147]. Thermostats can regulate heating, ventilation, and air conditioning systems, making them a viable tool for demand optimization. Recent studies provided evidence of the effects of smart thermostats on energy conservation and peak load reduction in residential and commercial buildings. Findings indicate that peak load reductions ranging from 10% to 35% and energy savings up to 17% can be achieved using smart thermostats [147].

Mendez et al. [150] have identified six behavioral and thirteen usability issues associated with adopting smart thermostats. These challenges and issues led to a failure among users to use smart thermostats correctly, resulting in increased energy consumption. Accordingly, they proposed a gamification framework to tackle the behavior and usability problems to motivate end-users to adopt smart thermostats more effectively.

One challenge in integrating smart thermostats into SEG is that the data acquired solely from smart thermostats may not be sufficient to provide comprehensive feedback to users. Additional data, such as the occupancy status of the building, is needed to ensure accurate analysis and effective feedback. A more robust and comprehensive understanding of energy usage patterns can be achieved by triangulating multiple sources of data, including smart thermostat data, occupancy data, indoor temperature, and potentially other relevant environmental or user behavior data.

Additionally, the potential of connecting thermostats to the grid and enabling utility companies to remotely control them by adjusting the setpoint temperature presents an opportunity [151], which can be leveraged for SEG to integrate this technology.

Data integration in SEG is pivotal in enabling personalized experiences, targeted interventions, and actionable insights for players. Advanced data collection tools, such as smart meters and smart thermostats, present opportunities for scaling up these platforms. Moreover, integrating data from various sources allows for a more comprehensive understanding of energy usage patterns and user preferences, leading to more effective and engaging gaming experiences. These data-driven insights significantly contribute to the development of more robust performance indicators for users, enabling researchers to evaluate the impact and effectiveness of SEG with greater precision and accuracy, which is further discussed in the following section.

4. Performance Assessment

A wide range of approaches and considerations are employed in assessing the performance of SEG, as illustrated in Table 4. These assessments encompass various aspects, including user performance, behavior, engagement and motivation, cognition, social interactions, and more.

Based on a proposal by Kim et al. [114] the metrics devised for evaluating the energy performance of the serious game users can be classified into three primary categories. Firstly, self-assessment of one's current status involves the evaluation of one's present standing and progress. Secondly, monitoring oneself using personal historical data facilitates tracking and observing individual energy consumption patterns and trends, thereby identifying areas that warrant improvement. By leveraging their historical data, users can gain valuable insights and make informed decisions to optimize their energy usage. Lastly, the evaluation of potential behavioral impact focuses on analyzing and predicting changes in individuals' behavior resulting from specific interventions. This category enables researchers and practitioners to anticipate the potential consequences of their initiatives, interventions, or policies, thereby informing the development of effective strategies for promoting positive behavioral changes.

To enhance comprehensibility and practical application, tangible metrics such as kWh electricity consumption, m^3 fuel consumption, CO_2 production and/or emission reduction, and other relevant units are used to gauge users' performance, progress, and environmental impact within the application.

A commonly used approach in most studies is the pre-post evaluation method [51,52,56,57,66]. This method involves assessing participants' energy consumption before and after introducing an intervention or feedback. In the phase before the intervention, which serves as the baseline, no feedback or intervention is provided to the participants. During this phase, researchers gather energy consumption data from historical records. It provides valuable insights into participants' typical energy consumption habits and serves as a benchmark for evaluating any changes following the intervention. Additionally, the pre-post evaluation is used to assess energy literacy and acquisition of energy-related knowledge, using surveys before and after the intervention to observe changes in knowledge, behavior, and social processes [152,153]. The potential of developed applications to engage users in energy-related activities beyond the initial gameplay experience and over the long term is a topic that was only addressed in a limited number of studies [66].

While the visualization of gamification elements and scenarios is used in existing studies, data visualization is also widely implemented to provide players with an overview of energy usage. Energy-related data are visualized using different forms, such as charts, graphs, and gauges [154]. However, the ability of users to interpret and make informed decisions based on trends and patterns remains an issue that requires further exploration [155].

One of the primary areas of investigation in previous studies is the assessment of user engagement by monitoring user activity on the interface, which can include the amount of time spent on the application, the information accessed, the preferred game element, and the actions taken.

In this regard, Kotsopoulos et al. [156] proposed a new measure named "gamification quotient" to assess the content of a gamified app in terms of game design elements. This measure was established in response to previous research, which found that gamified environments lacked sufficient tools to engage users effectively [157]. The measure evaluates the gamification quotient of an app based on the inclusion of more advanced and significant gamification design elements. Its primary purpose is to answer the question, "How gamified is an application?".

5. Conclusions and Future Directions

The field of SEG gained increasing attention among researchers, as these games offer an interactive and evolving platform for engaging users in energy-related topics and applications. They effectively provided experiences that enhance users' understanding of the abstract energy concept, which can often be challenging to grasp through traditional educational approaches.

However, challenges in designing and implementing SEG caused certain issues that need to be addressed. One of the key challenges lies in carefully selecting and designing game elements to ensure they effectively convey energy-related concepts and engage users. Suboptimal design choices have the potential to impede the learning experience and user engagement. Notable examples of these challenges include complexity overload, misaligned rewards, an overabundance of gamification elements, inadequate integration of educational content, and a deficiency of real-world contextualization.

When incorporating gamification features, it is important to consider creating a streamlined and effective environment. This involves removing extraneous elements that have the potential to distract individuals from the objectives of an energy game.

The issue of establishing an effective incentive structure within SEG to foster genuine behavior change and mitigate the risk of false or misguided incentives is a critical consideration. Previous research never sufficiently addressed the comprehensive cycle of behavioral change within this context. To achieve lasting alterations in behavior, it is imperative to integrate gamification components with state-of-the-art behavioral change models. In this regard, it is important to notice that most of these studies concentrated on influencing the determinants of behavior, such as attitudes and beliefs, without contextualizing the intervention in the process of behavioral change, including precontemplation, contemplation, preparation, action, and maintenance steps.

Building up from the previous point of a successful gamification and unhindered user experience, a remedy could be designing with "flow" in the mind of the user. The "flow" theory suggests that individuals reach a state of optimal experience, or "flow" when the challenge of an activity is matched with their skills' level. In this state, people become completely absorbed in their activity, experience heightened focus, and can even lose sense of time.

One of the main limitations of previous studies is that energy conservation receives the predominant and exclusive focus. In contrast, other important aspects of DSM, such as DR and self-consumption, are relatively overlooked. This narrow focus limits the comprehensive understanding of the potential benefits and synergies achieved through a holistic approach. In this regard, previous studies failed to fully consider the perspectives and involvement of different electricity system operators, including transmission system operators, distribution system operators, market operators, and aggregators. The absence of operators' considerations restricts the effectiveness and realism of DSM strategies within SEG. Establishing interactive feedback loops between operators and users facilitates the exchange of information, enabling operators to communicate grid conditions, pricing signals, and incentives to the users. Simultaneously, users can provide feedback on their energy consumption patterns, DR actions, and self-consumption practices, facilitating a collaborative and iterative learning and improvement process [56]. While some efforts were made in previous studies to involve operators, their role was often limited to observing demand without meaningful user interaction.

Another primary drawback observed in previous studies is the constrained scalability and limited generalizability of their findings. They often suffer from a small sample size or focus on specific populations, which restricts the applicability of their findings to real-world scenarios. Small sample sizes limit the statistical power of the studies and can lead to biased results or findings that may not hold when applied to a larger population. While researchers did not intend to use small sample sizes, their struggles convincing a larger pool of participants to participate in their research contributed to this issue. Another similar challenge arises when participants lose their motivation midway through the research and voluntarily drop out. As the initial excitement of the intervention wears off, researchers noticed a decline in the participants' interest and commitment to completing the challenges. After a few weeks, they become less actively involved in the intervention activities and eventually discontinue their participation altogether. This challenge reduces the sample size further and introduces potential bias in the results. When participants lose interest or fail to follow through with the study, their data might not accurately represent the entire population under investigation. This can undermine the reliability and validity of the study's findings. To address this issue, some researchers went beyond just virtual rewards and provided real-life incentives or rewards.

The limited duration of studies, typically ranging from a few weeks to a few months, poses another significant challenge. Energy behavior change often demands continuous reinforcement and ongoing engagement, aspects that might not be thoroughly assessed in shorter-term studies. Consequently, this limitation led to serious difficulties in accurately assessing users' performance and progress in adopting sustainable energy behaviors. Short-term studies fail to account for potential fluctuations in participants' motivation or external factors, such as the impact of weather conditions on energy consumption. Moreover, none of the previous studies effectively assessed and reported the long-term effectiveness of energy games after the intervention period. Furthermore, it was noticed that the seasonal bias in the scheduling of some studies could potentially impact the results. For instance, several studies initiate the experimentation phase during winter months and end in summer months. This period coincides with a natural reduction in energy usage due to milder weather conditions, which could confound the results, leading to overestimating the games' effectiveness in inducing energy-saving behaviors. Considering these limitations, we propose the need for a future study designed with a longitudinal approach, extending over a period of a year or more. The continuation of these studies, adopting a more longitudinal perspective, can provide a deeper understanding of the potential of serious games as an educational tool for energy applications.

Considering the data integration challenges, the primary hurdle lies in the accessibility of smart technologies for users. Without readily accessible technologies, data collection from various sources becomes difficult or even impossible. In many research projects, these technologies were provided to users for free, which, while beneficial for their participation, diminishes the likelihood of finding a scalable solution and creates further complications. In this context, games based on data from smart meters can offer users a good range of data, providing insightful information about their energy usage patterns. Additionally, utilizing standard smart meters offered by distribution system operators for such games can lead to a highly replicable solution, enabling widespread implementation and impact.

These limitations hindered the realization of the full potential and impact of SEGs within the broader field. When we compare the application of serious games in the energy sector with other domains, such as education or medicine, it becomes evident that the field could significantly benefit from embracing more holistic approaches and incorporating advanced methodologies. The relatively limited number of empirical studies that successfully implemented and rigorously tested these games on user behavior underscores the need for further research in this area. Furthermore, inadequately described methods and the absence of precise assessment criteria raised questions regarding the suitability of serious games in the energy sector, which should be addressed in future research endeavors.

In conclusion, serious games have the potential to promote various energy applications. By drawing on insights gained from past experiences, this review aspires to guide the evolution of SEG in a direction that fosters innovation and delivers more substantial impacts. As the prevalence of intermittent renewable energies and distributed resources continues to grow, active participation of energy users becomes essential for effectively balancing energy supply and demand across different geographical locations and varying weather patterns. This paper aims to elucidate the ways in which SEG can be applied to meet the evolving expectations of energy users within a rapidly changing energy landscape. However, the current research is limited, leaving ample opportunities for further exploration and investigation. Recommendations for future research center around enhancing gamification design, incorporating advanced behavioral change models, taking a comprehensive approach to address different aspects of DSM involving electricity system operators, and increasing sample sizes and study durations for greater applicability. To achieve more robust outcomes and innovative solutions, it is essential to emphasize inter/trans-disciplinary collaboration, bringing together expertise from diverse fields. In addition, another crucial area that requires attention in future research is the data integration process, particularly regarding privacy and ethical concerns. Currently, many studies lack proper consideration of these vital issues, posing potential privacy risks when integrating data from various sources, especially sensitive information about individuals. To ensure responsible data integration, researchers must address these ethical concerns adequately and implement measures to protect users' privacy throughout the data collection and analysis.

Every investigation is subject to methodological limitations. In this work, to avoid potential biases, different databases, such as Google Scholar, the Web of Science (WoS), and Scopus, were searched to retrieve relevant literature. The domain boundary was defined using the terms "serious game" and "energy", resulting in the acquisition of highly relevant and comprehensive references. During the articles selection process, reviews of their titles, abstracts, keywords, and in some cases, body content, were conducted. Therefore, even if authors do not use "serious game" in their title, abstract, or keywords, the chance of omitting important data is reduced. Furthermore, a cross-reference approach was also utilized to ensure a comprehensive coverage of the relevant literature and reduce the bias of applying a single method. However, it is noteworthy that the final selection was subjectively made.

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References

1. Nasrollahi, H.; Shirazizadeh, R.; Shirmohammadi, R.; Pourali, O.; Amidpour, M. Unraveling the Water-Energy-Food-Environment Nexus for Climate Change Adaptation in Iran: Urmia Lake Basin Case-Study. *Water* **2021**, *13*, 1282. [CrossRef]
2. European Commission. *Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions. A Green Deal Industrial Plan for the Net-Zero Age*; European Commission: Brussels, Belgium, 2023.
3. Oliveira, M.C.; Iten, M.; Fernandes, U. Modelling of a Solar Thermal Energy System for Energy Efficiency Improvement in a Ceramic Plant. In *Sustainable Energy Development and Innovation*; Springer: Berlin/Heidelberg, Germany, 2022; pp. 825–831. [CrossRef]
4. Di Lorenzo, G.; Stracqualursi, E.; Araneo, R. The Journey Towards the Energy Transition: Perspectives from the International Conference on Environment and Electrical Engineering (EEEIC). *Energies* **2022**, *15*, 6652. [CrossRef]
5. European Council. *European Council Conclusions*; European Council: Brussels, Belgium, 2014.
6. Weckmann, S.; Kuhlmann, T.; Sauer, A. Decentral Energy Control in a Flexible Production to Balance Energy Supply and Demand. *Procedia CIRP* **2017**, *61*, 428–433. [CrossRef]
7. Bale, C.S.; Varga, L.; Foxon, T.J. Energy and Complexity: New Ways Forward. *Appl. Energy* **2015**, *138*, 150–159. [CrossRef]
8. Shahzad, M.; Qu, Y.; Rehman, S.U.; Zafar, A.U. Adoption of Green Innovation Technology to Accelerate Sustainable Development among Manufacturing Industry. *J. Innov. Knowl.* **2022**, *7*, 100231. [CrossRef]
9. Krumm, A.; Süsser, D.; Blechinger, P. Modelling Social Aspects of the Energy Transition: What Is the Current Representation of Social Factors in Energy Models? *Energy* **2022**, *239*, 121706. [CrossRef]
10. Burgess, J.; Nye, M. Re-Materialising Energy Use through Transparent Monitoring Systems. *Energy Policy* **2008**, *36*, 4454–4459. [CrossRef]
11. Boomsma, C.; Hafner, R.; Pahl, S.; Jones, R.V.; Fuertes, A. Should We Play Games Where Energy Is Concerned? Perceptions of Serious Gaming as a Technology to Motivate Energy Behaviour Change among Social Housing Residents. *Sustainability* **2018**, *10*, 1729. [CrossRef]
12. Pahl, S.; Goodhew, J.; Boomsma, C.; Sheppard, S.R.J. The Role of Energy Visualization in Addressing Energy Use: Insights from the Eviz Project. *Front. Psychol.* **2016**, *7*, 92. [CrossRef] [PubMed]
13. Boomsma, C.; Goodhew, J.; Goodhew, S.; Pahl, S. Improving the Visibility of Energy Use in Home Heating in England: Thermal Images and the Role of Visual Tailoring. *Energy Res. Soc. Sci.* **2016**, *14*, 111–121. [CrossRef]
14. Buchanan, K.; Russo, R.; Anderson, B. The Question of Energy Reduction: The Problem(s) with Feedback. *Energy Policy* **2015**, *77*, 89–96. [CrossRef]

15. Lampropoulos, I.; Alskaif, T.; Broek, M.v.D.; van Sark, W.; van Oostendorp, H. A Method for Developing a Game-Enhanced Tool Targeting Consumer Engagement in Demand Response Mechanisms. In *Mediterranean Cities and Island Communities*; Springer: Berlin/Heidelberg, Germany, 2018; pp. 213–235. [CrossRef]
16. Delemere, E.; Liston, P. Exploring the Use of Behavioural Techniques in Serious Games for Energy Efficiency: A Systematic Review and Content Analysis. *Behav. Soc. Issues* **2022**, *31*, 451–479. [CrossRef]
17. Bennett, S.; Maton, K.; Kervin, L. The 'Digital Natives' Debate: A Critical Review of the Evidence. *Br. J. Educ. Technol.* **2008**, *39*, 775–786. [CrossRef]
18. Wu, X.; Liu, S.; Shukla, A. Serious Games as an Engaging Medium on Building Energy Consumption: A Review of Trends, Categories and Approaches. *Sustainability* **2020**, *12*, 8508. [CrossRef]
19. Lucero, A.; Karapanos, E.; Arrasvuori, J.; Korhonen, H. Playful or Gameful? *Interactions* **2014**, *21*, 34–39. [CrossRef]
20. Zichermann, G.; Cunningham, C. *Gamification by Design: Implementing Game Mechanics in Web and Mobile Apps*; O'Reilly Media: Sebastopol, CA, USA, 2011; ISBN 1449397670.
21. Hanus, M.D.; Fox, J. Assessing the Effects of Gamification in the Classroom: A Longitudinal Study on Intrinsic Motivation, Social Comparison, Satisfaction, Effort, and Academic Performance. *Comput. Educ.* **2015**, *80*, 152–161. [CrossRef]
22. Hamari, J.; Koivisto, J.; Sarsa, H. Does Gamification Work?—A Literature Review of Empirical Studies on Gamification. In Proceedings of the 2014 47th Hawaii International Conference on System Sciences, Waikoloa, HI, USA, 6–9 January 2014; pp. 3025–3034.
23. Argilés, F.T.; Chou, Y.-K. *Actionable Gamification: Beyond Points, Badges and Leaderboards*; Revista Internacional de Organizaciones; Octalysis Media: Fremont, CA, USA, 2017; Volume 137. [CrossRef]
24. Ouariachi, T.; Elving, W.J.L.; Pierie, F. Playing for a Sustainable Future: The Case of We Energy Game as an Educational Practice. *Sustainability* **2018**, *10*, 3639. [CrossRef]
25. Damaševičius, R.; Maskeliūnas, R.; Blažauskas, T. Serious Games and Gamification in Healthcare: A Meta-Review. *Information* **2023**, *14*, 105. [CrossRef]
26. Goi, C.L. Gamification in Business Education: Visualizing Bibliometric Networks Analysis. *J. Educ. Bus.* **2022**, *98*, 229–241. [CrossRef]
27. Herzig, P.; Ameling, M.; Schill, A. A Generic Platform for Enterprise Gamification. In Proceedings of the 2012 Joint Working IEEE/IFIP Conference on Software Architecture and European Conference on Software Architecture, Helsinki, Finland, 20–24 August 2012; pp. 219–223.
28. Contreras-Espinosa, R.S.; Blanco-M, A. A Literature Review of E-Government Services with Gamification Elements. *Int. J. Public Adm.* **2021**, *45*, 964–980. [CrossRef]
29. Harviainen, J.T.; Hassan, L. Governmental Service Gamification. *Int. J. Innov. Digit. Econ.* **2019**, *10*, 1–12. [CrossRef]
30. Hassan, L.; Hamari, J. Gamification of E-Participation: A Literature Review. In Proceedings of the 52nd Hawaii International Conference on System Sciences, Maui, HI, USA, 8–11 January 2019.
31. Coronado Escobar, J.E.; Vasquez Urriago, A.R. Gamification: An Effective Mechanism to Promote Civic Engagement and Generate Trust? In Proceedings of the 8th International Conference on Theory and Practice of Electronic Governance, Guimaraes, Portugal, 27–30 October 2014; ACM: New York, NY, USA, 2014; pp. 514–515.
32. Thiel, S.-K.; Lehner, U. Exploring the Effects of Game Elements in M-Participation. In Proceedings of the 2015 British HCI Conference, Lincolnshire, UK, 13–17 July 2015; ACM: New York, NY, USA, 2015; pp. 65–73.
33. Despeisse, M. Teaching Sustainability Leadership in Manufacturing: A Reflection on the Educational Benefits of the Board Game Factory Heroes. *Procedia CIRP* **2018**, *69*, 621–626. [CrossRef]
34. Romero, M.; Usart, M.; Ott, M. Can Serious Games Contribute to Developing and Sustaining 21st Century Skills? *Games Cult.* **2015**, *10*, 148–177. [CrossRef]
35. Olszewski, R.; Pałka, P.; Turek, A. Solving "Smart City" Transport Problems by Designing Carpooling Gamification Schemes with Multi-Agent Systems: The Case of the So-Called "Mordor of Warsaw". *Sensors* **2018**, *18*, 141. [CrossRef] [PubMed]
36. Lidia, A.-C.; Julio, R.-T.; Petra, D.S.-P.; Rafael, P.-J. How to Encourage Recycling Behaviour? The Case of WasteApp: A Gamified Mobile Application. *Sustainability* **2018**, *10*, 1544. [CrossRef]
37. Cominola, A.; Nanda, R.; Giuliani, M.; Piga, D.; Castelletti, A.; Rizzoli, A.E.; Maziotis, A.; Garrone, P.; Harou, J.J.; Cominola, A.; et al. The SmartH_2O Project: A Platform Supporting Residential Water Management through Smart Meters and Data Intensive Modeling. In Proceedings of the AGUFM Fall Meeting 2014, San Francisco, CA, USA, 15–19 December 2014. IN23E-06.
38. Rizzoli, A.E.; Castelletti, A.; Fraternali, P.; Novak, J. Demo Abstract: SmartH2O, Demonstrating the Impact of Gamification Technologies for Saving Water. *Comput. Sci.-Res. Dev.* **2017**, *33*, 275–276. [CrossRef]
39. Ho, M.-T.; Nguyen, T.-H.T.; Nguyen, M.-H.; La, V.-P.; Vuong, Q.-H. Virtual Tree, Real Impact: How Simulated Worlds Associate with the Perception of Limited Resources. *Humanit. Soc. Sci. Commun.* **2022**, *9*, 213. [CrossRef]
40. Castellano, G.; De Carolis, B.; D'errico, F.; Macchiarulo, N.; Rossano, V. PeppeRecycle: Improving Children's Attitude Toward Recycling by Playing with a Social Robot. *Int. J. Soc. Robot.* **2021**, *13*, 97–111. [CrossRef]
41. Bang, M.; Torstensson, C.; Katzeff, C. *The PowerHouse: A Persuasive Computer Game Designed to Raise Awareness of Domestic Energy Consumption*; Springer: Berlin/Heidelberg, Germany, 2006; pp. 123–132. [CrossRef]
42. Johnson, D.; Horton, E.; Mulcahy, R.; Foth, M. Gamification and Serious Games within the Domain of Domestic Energy Consumption: A Systematic Review. *Renew. Sustain. Energy Rev.* **2017**, *73*, 249–264. [CrossRef]

43. Gustafsson, A.; Bång, M.; Svahn, M. Power Explorer: A Casual Game Style for Encouraging Long Term Behavior Change among Teenagers. In Proceedings of the International Conference on Advances in Computer Entertainment Technology, Athens, Greece, 29–32 October 2009; ACM: New York, NY, USA, 2009; pp. 182–189.
44. Morganti, L.; Pallavicini, F.; Cadel, E.; Candelieri, A.; Archetti, F.; Mantovani, F. Gaming for Earth: Serious Games and Gamification to Engage Consumers in pro-Environmental Behaviours for Energy Effi-ciency. *Energy Res. Soc. Sci.* **2017**, *29*, 95–102. [CrossRef]
45. Méndez, J.I.; Ponce, P.; Peffer, T.; Meier, A.; Molina, A. Gamified HMI as a Response for Implementing a Smart-Sustainable University Campus. In *Smart and Sustainable Collaborative Networks 4.0*; IFIP Advances in Information and Communication Technology, 629 IFIPAICT; Springer: Berlin/Heidelberg, Germany, 2021; pp. 683–691. [CrossRef]
46. Hafner, R.J.; Pahl, S.; Jones, R.V.; Fuertes, A. Energy Use in Social Housing Residents in the UK and Recommendations for Developing Energy Behaviour Change Inter-ventions. *J. Clean. Prod.* **2020**, *251*, 119643. [CrossRef]
47. Liu, S.; Iweka, O.; Shukla, A.; Wernham, G.; Hussain, A.; Day, R.; Gaterell, M.; Petridis, P.; Van Der Horst, D. Impact of Emerging Interaction Techniques on Energy Use in the UK Social Housing. *Futur. Cities Environ.* **2018**, *4*, 8. [CrossRef]
48. Polyanska, A.; Andriiovych, M.; Generowicz, N.; Kulczycka, J.; Psyuk, V. Gamification as an Improvement Tool for HR Management in the Energy Industry—A Case Study of the Ukrainian Market. *Energies* **2022**, *15*, 1344. [CrossRef]
49. Figol, N.; Faichuk, T.; Pobidash, I.; Trishchuk, O.; Teremko, V. Application Fields of Gamification. *Rev. Amaz. Investig.* **2021**, *10*, 93–100. [CrossRef]
50. Gamberini, L.; Corradi, N.; Zamboni, L.; Perotti, M.; Cadenazzi, C.; Mandressi, S.; Jacucci, G.; Tusa, G.; Spagnolli, A.; Björkskog, C.; et al. Saving Is Fun: Designing a Persuasive Game for Power Conservation. In Proceedings of the 8th International Conference on Advances in Computer Entertainment Technology, Lisbon Portugal, 8–11 November 2011; ACM: New York, NY, USA, 2011; pp. 1–7.
51. Casals, M.; Gangolells, M.; Macarulla, M.; Forcada, N.; Fuertes, A.; Jones, R.V. Assessing the Effectiveness of Gamification in Reducing Domestic Energy Consumption: Lessons Learned from the Ener-GAware Project. *Energy Build.* **2020**, *210*, 109753. [CrossRef]
52. Casals, M.; Gangolells, M.; Macarulla, M.; Fuertes, A.; Vimont, V.; Pinho, L.M. A Serious Game Enhancing Social Tenants' Behavioral Change towards Energy Efficiency. In Proceedings of the GIoTS 2017—Global Internet of Things Summit, Geneva, Switzerland, 6–9 June 2017. [CrossRef]
53. Fraternali, P.; Cellina, F.; Herrera, S.; Krinidis, S.; Pasini, C.; Rizzoli, A.E.; Rottondi, C.; Tzovaras, D. A Socio-Technical System Based on Gamification Towards Energy Savings. In Proceedings of the 2018 IEEE International Conference on Pervasive Computing and Communications Workshops, PerCom Workshops 2018, Athens, Greece, 19–23 March 2018; pp. 59–64. [CrossRef]
54. Fraternali, P.; Herrera, S.; Novak, J.; Melenhorst, M.; Tzovaras, D.; Krinidis, S.; Rizzoli, A.E.; Rottondi, C.; Cellina, F. EnCOMPASS—An Integrative Approach to Behavioural Change for Energy Saving. In Proceedings of the GIoTS 2017—Global Internet of Things Summit, Geneva, Switzerland, 6–9 June 2017; pp. 1–6. [CrossRef]
55. Fraternali, P.; Gonzalez, S.L.H.G. EnCOMPASS, Demonstrating the Impact of Gamification and Persuasive Visualizations for Energy Saving. *Energy Inform.* **2019**, *2*, 49–52.
56. Fijnheer, J.D.L.; van Oostendorp, H.; Veltkamp, R.C. Enhancing Energy Conservation by a Household Energy Game. In *Games and Learning Alliance*; Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics); Springer: Berlin/Heidelberg, Germany, 2019; Volume 11385, pp. 257–266.
57. Fijnheer, J.D.L.; Van Oostendorp, H.; Veltkamp, R. Household Energy Conservation Intervention: A Game versus Dashboard Comparison. *Int. J. Serious Games* **2019**, *6*, 23–36. [CrossRef]
58. Fijnheer, J.D.; van Oostendorp, H. Steps to Design a Household Energy Game. In *Games and Learning Alliance*; Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics); Springer: Berlin/Heidelberg, Germany, 2016; Volume 9599, pp. 12–22.
59. Kashani, A.; Ozturk, Y. Residential Energy Consumer Behavior Modification via Gamification. In Proceedings of the 2017 IEEE 6th International Conference on Renewable Energy Research and Applications (ICRERA), San Diego, CA, USA, 5–8 November 2017; pp. 1221–1225. [CrossRef]
60. Zeile, P.; Elisei, P.; Ryser, J.; Stöglehner, G.; Gebetsroither-Geringer, E.; Pfeiffer, A.; Goels, M.; Worster, J.; Meissner, E.; Graf, A.; et al. Can Gamification Be Used for Spatial Energy Data Collection? Experiences Gained from the Development of the HotCity Game to Collect Urban Waste Heat Sources. In Proceedings of the 26th International Conference on Urban Development, Regional Planning and Information Society, Vienna, Austria, 7–10 September 2021.
61. Bourazeri, A.; Pitt, J. Collective Attention and Active Consumer Participation in Community Energy Systems. *Int. J. Hum.-Comput. Stud.* **2018**, *119*, 1–11. [CrossRef]
62. Bourazeri, A.; Pitt, J. Collective Awareness for Collective Action in Socio-Technical Systems. In Proceedings of the 2014 IEEE Eighth International Conference on Self-Adaptive and Self-Organizing Systems Workshops, London, UK, 8–12 September 2014; pp. 90–95.
63. Bourazeri, A.; Pitt, J. Social Mpower: A Serious Game for Self-Organisation in Socio-Technical Systems. In Proceedings of the 2014 IEEE Eighth International Conference on Self-Adaptive and Self-Organizing Systems, London, UK, 8–12 September; pp. 199–200.
64. Hedin, B.; Lundstrom, A.; Westlund, M.; Markstrom, E. The Energy Piggy Bank—A Serious Game for Energy Conservation. In Proceedings of the 2017 Sustainable Internet and ICT for Sustainability (SustainIT), Funchal, Portugal, 6–7 December 2017; pp. 1–6.

65. Reeves, B.; Cummings, J.J.; Scarborough, J.K.; Flora, J.; Anderson, D. Leveraging the Engagement of Games to Change Energy Behavior. In Proceedings of the 2012 International Conference on Collaboration Technologies and Systems (CTS), Denver, CO, USA, 21–25 May 2012; pp. 354–358.
66. Wemyss, D.; Castri, R.; De Luca, V.; Cellina, F.; Frick, V.; Lobsiger-Kägi, E.; Gabani Bianchi, P.; Hertach, C.; Kuehn, T.; Carabias, V. Keeping up with the Joneses: Examining Community-Level Collaborative and Competitive Game Mechanics to Enhance Houshold Electricity-Saving Behaviour. In Proceedings of the 4th European Conference on Behaviour and Energy Efficiency, Coimbra, Portugal, 8–9 September 2016.
67. Hagen, B.; Middel, A.; Pijawka, D. European Climate Change Perceptions: Public Support for Mitigation and Adaptation Policies. *Environ. Policy Gov.* **2015**, *26*, 170–183. [CrossRef]
68. Reckien, D.; Eisenack, K. Climate Change Gaming on Board and Screen. *Simul. Gaming* **2013**, *44*, 253–271. [CrossRef]
69. Moser, S.C. Communicating Climate Change: History, Challenges, Process and Future Directions. *WIREs Clim. Chang.* **2009**, *1*, 31–53. [CrossRef]
70. Paone, A.; Bacher, J.-P. The Impact of Building Occupant Behavior on Energy Efficiency and Methods to Influence It: A Review of the State of the Art. *Energies* **2018**, *11*, 953. [CrossRef]
71. Capehart, B.L.; Kennedy, W.J.; Turner, W.C. *Guide to Energy Management*, 8th ed.; International Version; River Publishers; The Fairmont Press, Inc.: Lilburn, GA, USA, 2016; ISBN 9781003152002.
72. Schick, L.; Gad, C. Flexible and Inflexible Energy Engagements—A Study of the Danish Smart Grid Strategy. *Energy Res. Soc. Sci.* **2015**, *9*, 51–59. [CrossRef]
73. Buchanan, K.; Banks, N.; Preston, I.; Russo, R. The British Public's Perception of the UK Smart Metering Initiative: Threats and Opportunities. *Energy Policy* **2016**, *91*, 87–97. [CrossRef]
74. Vine, D.; Buys, L.; Morris, P. The Effectiveness of Energy Feedback for Conservation and Peak Demand: A Literature Review. *Open J. Energy Effic.* **2013**, *02*, 7–15. [CrossRef]
75. Sintov, N.D.; Eschultz, P.W. Unlocking the Potential of Smart Grid Technologies with Behavioral Science. *Front. Psychol.* **2015**, *6*, 410. [CrossRef]
76. Darby, S. *The Effectiveness of Feedback on Energy Consumption. A Review for DEFRA of the Literature on Metering, Billing and direct Displays*; Environmental Change Institute, University of Oxford: Oxfrod, UK, 2006; Volume 486, p. 26.
77. Agarwal, R.; Garg, M.; Tejaswini, D.; Garg, V.; Srivastava, P.; Mathur, J.; Gupta, R. A Review of Residential Energy Feedback Studies. *Energy Build.* **2023**, *290*, 113071. [CrossRef]
78. Paolo, B.; Tiago, R.S.; Paolo, Z. *Consumer Feedback Systems: How Much Energy Saving Will They Deliver and for How Long?* ACEEE Summer Study on Energy Efficiency in Buildings; American Council for an Energy-Efficient Economy: Washington, DC, USA, 2016.
79. Fischer, C. Feedback on Household Electricity Consumption: A Tool for Saving Energy? *Energy Effic.* **2008**, *1*, 79–104. [CrossRef]
80. Attari, S.Z.; DeKay, M.L.; Davidson, C.I.; de Bruin, W.B. Public Perceptions of Energy Consumption and Savings. *Proc. Natl. Acad. Sci. USA* **2010**, *107*, 16054–16059. [CrossRef]
81. Zangheri, P.; Serrenho, T.; Bertoldi, P. Energy Savings from Feedback Systems: A Meta-Studies' Review. *Energies* **2019**, *12*, 3788. [CrossRef]
82. Gellings, C. The Concept of Demand-Side Management for Electric Utilities. *Proc. IEEE* **1985**, *73*, 1468–1470. [CrossRef]
83. Jabir, H.J.; Teh, J.; Ishak, D.; Abunima, H. Impacts of Demand-Side Management on Electrical Power Systems: A Review. *Energies* **2018**, *11*, 1050. [CrossRef]
84. Lampropoulos, I.; Kling, W.L.; Ribeiro, P.F.; Berg, J.V.D. History of Demand Side Management and Classification of Demand Response Control Schemes. In Proceedings of the 2013 IEEE Power & Energy Society General Meeting, Vancouver, BC, Canada, 21–25 July 2013.
85. AlSkaif, T.; Lampropoulos, I.; Broek, M.v.D.; van Sark, W. Gamification-Based Framework for Engagement of Residential Customers in Energy Applications. *Energy Res. Soc. Sci.* **2018**, *44*, 187–195. [CrossRef]
86. Bartle, R. Hearts, Clubs, Diamonds, Spades: Players Who Suit MUDs. *J. MUD Res.* **1996**, *1*, 19.
87. Forehand, M. Bloom's Taxonomy: Original and Revised. In *Emerging Perspectives on Learning, Teaching, and Technology*; Global Text Project: Athens, GA, USA, 2005; p. 8. Available online: http://www.coe.uga.edu/epltt/bloom.htm (accessed on 6 September 2023).
88. Sorrell, S. Jevons' Paradox Revisited: The Evidence for Backfire from Improved Energy Efficiency. *Energy Policy* **2009**, *37*, 1456–1469. [CrossRef]
89. Giampietro, M.; Mayumi, K. Unraveling the Complexity of the Jevons Paradox: The Link Between Innovation, Efficiency, and Sustainability. *Front. Energy Res.* **2018**, *6*, 349753. [CrossRef]
90. Fraternali, P.; Gonzalez, S.L.H. An Augmented Reality Game for Energy Awareness. In *Games and Learning Alliance*; Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics); Springer: Berlin/Heidelberg, Germany, 2019; Volume 11754, pp. 629–638.
91. Kendel, A.; Lazaric, N.; Maréchal, K. What Do People 'Learn by Looking' at Direct Feedback on Their Energy Consumption? Results of a Field Study in Southern France. *Energy Policy* **2017**, *108*, 593–605. [CrossRef]
92. Dehler, J.; Keles, D.; Telsnig, T.; Fleischer, B.; Baumann, M.; Fraboulet, D.; Faure-Schuyer, A.; Fichtner, W. Self-Consumption of Electricity from Renewable Sources. In *Europe's Energy Transition—Insights for Policy Making*; Elsevier: Amsterdam, The Netherlands, 2017; pp. 225–236.

93. Vilarinho, T.; Farshchian, B.; Wienhofen, L.W.; Franang, T.; Gulbrandsen, H. Combining Persuasive Computing and User Centered Design into an Energy Awareness System for Smart Houses. In Proceedings of the 12th International Conference on Intelligent Environments, London, UK, 14–16 September 2016; pp. 32–39. [CrossRef]
94. Luthander, R.; Widén, J.; Nilsson, D.; Palm, J. Photovoltaic Self-Consumption in Buildings: A Review. *Appl. Energy* **2015**, *142*, 80–94. [CrossRef]
95. Litjens, G.; Worrell, E.; van Sark, W.G.J.H.M. Influence of Demand Patterns on the Optimal Orientation of Photovoltaic Systems. *Sol. Energy* **2017**, *155*, 1002–1014. [CrossRef]
96. Rai, V.; Beck, A.L. Play and Learn: Serious Games in Breaking Informational Barriers in Residential Solar Energy Adoption in the United States. *Energy Res. Soc. Sci.* **2017**, *27*, 70–77. [CrossRef]
97. Papaioannou, T.G.; Dimitriou, N.; Vasilakis, K.; Schoofs, A.; Nikiforakis, M.; Pursche, F.; Deliyski, N.; Taha, A.; Kotsopoulos, D.; Bardaki, C.; et al. An IoT-Based Gamified Approach for Reducing Occupants' Energy Wastage in Public Buildings. *Sensors* **2018**, *18*, 537. [CrossRef]
98. Olszewski, R.; Pałka, P.; Wendland, A.; Kamiński, J. A Multi-Agent Social Gamification Model to Guide Sustainable Urban Photovoltaic Panels Installation Policies. *Energies* **2019**, *12*, 3019. [CrossRef]
99. Salim, H.; Stewart, R.A.; Sahin, O.; Sagstad, B.; Dudley, M. R3SOLVE: A Serious Game to Support End-of-Life Rooftop Solar Panel Waste Management. *Sustainability* **2021**, *13*, 12418. [CrossRef]
100. Gnauk, B.; Dannecker, L.; Hahmann, M. Leveraging Gamification in Demand Dispatch System. In *ACM International Conference Proceeding Series, Proceedings of the 15th International Conference on Database Theory, Berlin Germany, 30 March 2012*; ACM: New York, NY, USA, 2012; pp. 103–110. [CrossRef]
101. Wang, Y.; Chen, Q.; Kang, C.; Zhang, M.; Wang, K.; Zhao, Y. Load Profiling and Its Application to Demand Response: A Review. *Tsinghua Sci. Technol.* **2015**, *20*, 117–129. [CrossRef]
102. Konstantakopoulos, I.C.; Barkan, A.R.; He, S.; Veeravalli, T.; Liu, H.; Spanos, C. A Deep Learning and Gamification Approach to Energy Conservation at Nanyang Technological University. *arXiv* **2018**, arXiv:1809.05142. [CrossRef]
103. Jin, M.; Feng, W.; Marnay, C.; Spanos, C. Microgrid to Enable Optimal Distributed Energy Retail and End-User Demand Response. *Appl. Energy* **2018**, *210*, 1321–1335. [CrossRef]
104. Nykyri, M.; Karkkainen, T.J.; Annala, S.; Silventoinen, P. Review of Demand Response and Energy Communities in Serious Games. *IEEE Access* **2022**, *10*, 91018–91026. [CrossRef]
105. Wang, K.; Tekler, Z.D.; Cheah, L.; Herremans, D.; Blessing, L. Evaluating the Effectiveness of an Augmented Reality Game Promoting Environmental Action. *Sustainability* **2021**, *13*, 13912. [CrossRef]
106. Fijnheer, J.D.; van Oostendorp, H.; Giezeman, G.-J.; Veltkamp, R.C. Competition in a Household Energy Conservation Game. *Sustainability* **2021**, *13*, 11991. [CrossRef]
107. Bandura, A. *Social Learning Theory*; Prentice Hall: Englewood Cliffs, NJ, USA, 1977.
108. Ouariachi, T.; Olvera-Lobo, M.D.; Gutiérrez-Pérez, J. Analyzing Climate Change Communication Through Online Games. *Sci. Commun.* **2017**, *39*, 10–44. [CrossRef]
109. Grevet, C.; Mankoff, J.; Anderson, S.D. Design and Evaluation of a Social Visualization Aimed at Encouraging Sustainable Behavior. In Proceedings of the 2010 43rd Hawaii International Conference on System Sciences, Honolulu, HI, USA, 5–8 January 2010; pp. 1–8. [CrossRef]
110. Muchnik, A.; Casas, P.F.I.; Zamyatina, O.; Casanovas, J.; Muchnik, A.; Casas, P.F.I.; Zamyatina, O.; Casanovas, J. Analysis of the Gamification Applications to Improve the Energy Savings in Residential Buildings. *WSEAS Trans. Comput.* **2022**, *21*, 88–96. [CrossRef]
111. Polk, D.E.; King, C.M.; Heller, K. Community-Based Interventions. In *Cambridge Handbook of Psychology, Health and Medicine*; Cambridge University Press: Cambridge, UK, 2001; pp. 344–348.
112. Wemyss, D.; Castri, R.; Cellina, F.; De Luca, V.; Lobsiger-Kägi, E.; Carabias, V. Examining Community-Level Collaborative vs. Competitive Approaches to Enhance Household Electricity-Saving Behavior. *Energy Effic.* **2018**, *11*, 2057–2075. [CrossRef]
113. Jain, R.K.; Gulbinas, R.; Taylor, J.E.; Culligan, P.J. Can Social Influence Drive Energy Savings? Detecting the Impact of Social Influence on the Energy Consumption Behavior of Networked Users Exposed to Normative Eco-Feedback. *Energy Build.* **2013**, *66*, 119–127. [CrossRef]
114. Kim, H.; Ham, S.; Promann, M.; Devarapalli, H.; Bihani, G.; Ringenberg, T.; Kwarteng, V.; Bilionis, I.; Braun, J.E.; Rayz, J.T.; et al. MySmartE—An Eco-Feedback and Gaming Platform to Promote Energy Conserving Thermostat-Adjustment Behaviors in Multi-Unit Residential Buildings. *Build. Environ.* **2022**, *221*, 109252. [CrossRef]
115. Wendel, S. *Designing for Behavior Change: Applying Psychology and Behavioral Economics*; O'Reilly Media, Inc.: Sebastopol, CA, USA, 2013.
116. Huber, M.Z.; Hilty, L.M. Gamification and Sustainable Consumption: Overcoming the Limitations of Persuasive Technologies. In *ICT Innovations for Sustainability*; Springer: Berlin/Heidelberg, Germany, 2015; pp. 367–385.
117. Okpo, J.A.; Masthoff, J.; Dennis, M. Qualitative Evaluation of an Adaptive Exercise Selection Algorithm. In *Adjunct Proceedings of the 29th ACM Conference on User Modeling, Adaptation and Personalization, Utrecht, The Netherlands, 21–25 June 2021*; ACM: New York, NY, USA, 2021; pp. 167–174.
118. Schultz, P.W.; Nolan, J.M.; Cialdini, R.B.; Goldstein, N.J.; Griskevicius, V. The Constructive, Destructive, and Reconstructive Power of Social Norms. *Psychol. Sci.* **2007**, *18*, 429–434. [CrossRef]

119. Méndez, J.I.; Peffer, T.; Ponce, P.; Meier, A.; Molina, A. Empowering Saving Energy at Home through Serious Games on Thermostat Interfaces. *Energy Build.* **2022**, *263*, 112026. [CrossRef]
120. Prochaska, J.O.; Velicer, W.F. The Transtheoretical Model of Health Behavior Change. *Am. J. Health Promot.* **1997**, *12*, 38–48. [CrossRef] [PubMed]
121. Fu, Y.; Wu, W. Predicting Household Water Use Behaviour for Improved Hygiene Practices in Internet of Things Environment via Dynamic Behaviour Intervention Model. *IET Netw.* **2016**, *5*, 143–151. [CrossRef]
122. He, H.A.; Greenberg, S.; Huang, E.M. One Size Does Not Fit All. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, Atlanta, GA, USA, 10–15 April 2010; ACM: New York, NY, USA, 2010; pp. 927–936.
123. Fogg, B. A Behavior Model for Persuasive Design. In Proceedings of the 4th International Conference on Persuasive Technology, Claremont, CA, USA, 26–29 April 2009; ACM: New York, NY, USA, 2009; pp. 1–7.
124. Ajzen, I. From Intentions to Actions: A Theory of Planned Behavior. In *Action Control*; Springer: Berlin/Heidelberg, Germany, 1985; pp. 11–39.
125. Dennis, M.; Masthoff, J.; Mellish, C. Adapting Progress Feedback and Emotional Support to Learner Personality. *Int. J. Artif. Intell. Educ.* **2016**, *26*, 877–931. [CrossRef]
126. Fotios, S. A Revised Kruithof Graph Based on Empirical Data. *LEUKOS* **2016**, *13*, 3–17. [CrossRef]
127. Cigler, J.; Prívara, S.; Váňa, Z.; Žáčeková, E.; Ferkl, L. Optimization of Predicted Mean Vote Index within Model Predictive Control Framework: Computationally Tractable Solution. *Energy Build.* **2012**, *52*, 39–49. [CrossRef]
128. Csikszentmihalyi, M. *Flow: The Psychology of Optimal Experience*; Harper & Row: New York, NY, USA, 1990.
129. Hamari, J.; Shernoff, D.J.; Rowe, E.; Coller, B.; Asbell-Clarke, J.; Edwards, T. Challenging Games Help Students Learn: An Empirical Study on Engagement, Flow and Immersion in Game-Based Learning. *Comput. Hum. Behav.* **2016**, *54*, 170–179. [CrossRef]
130. Ryan, R.M.; Rigby, C.S.; Przybylski, A. The Motivational Pull of Video Games: A Self-Determination Theory Approach. *Motiv. Emot.* **2006**, *30*, 344–360. [CrossRef]
131. Frankel, D.; Heck, S.; Tai, H. *Using a Consumer-Segmentation Approach to Make Energy-Efficiency Gains in the Residential Market*; McKinsey and Company: Chicago, IL, USA, 2013.
132. Ponce, P.; Peffer, T.; Molina, A. Framework for Communicating with Consumers Using an Expectation Interface in Smart Thermostats. *Energy Build.* **2017**, *145*, 44–56. [CrossRef]
133. Peham, M.; Breitfuss, G.; Michalczuk, R. The "EcoGator" App: Gamification for Enhanced Energy Efficiency in Europe. In *ACM International Conference Proceeding Series, Proceedings of the Second International Conference on Technological Ecosystems for Enhancing, Salamanca, Spain, 1–3 October 2014*; ACM: New York, NY, USA, 2014; pp. 179–183. [CrossRef]
134. Albertarelli, S.; Fraternali, P.; Herrera, S.; Melenhorst, M.; Novak, J.; Pasini, C.; Rizzoli, A.-E.; Rottondi, C. A Survey on the Design of Gamified Systems for Energy and Water Sustainability. *Games* **2018**, *9*, 38. [CrossRef]
135. Martin, B.; Kwaku, Y.A. Designing at the Intersection of Gamification and Persuasive Technology to Incentivize Energy-Saving. In *Games and Learning Alliance*; Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics); Springer: Berlin/Heidelberg, Germany, 2019; Volume 11701, pp. 316–328.
136. Behi, B.; Arefi, A.; Jennings, P.; Pivrikas, A.; Gorjy, A.; Catalao, J.P.S. Consumer Engagement in Virtual Power Plants through Gamification. In Proceedings of the 2020 5th International Conference on Power and Renewable Energy, ICPRE 2020, Shanghai, China, 12–14 September 2020; pp. 131–137. [CrossRef]
137. Ponce, P.; Meier, A.; Méndez, J.I.; Peffer, T.; Molina, A.; Mata, O. Tailored Gamification and Serious Game Framework Based on Fuzzy Logic for Saving Energy in Connected Thermostats. *J. Clean Prod.* **2020**, *262*, 121167. [CrossRef]
138. Avila, M.; Méndez, J.I.; Ponce, P.; Peffer, T.; Meier, A.; Molina, A. Energy Management System Based on a Gamified Application for Households. *Energies* **2021**, *14*, 3445. [CrossRef]
139. Méndez, J.I.; Medina, A.; Ponce, P.; Peffer, T.; Meier, A.; Molina, A. Evolving Gamified Smart Communities in Mexico to Save Energy in Communities through Intelligent Interfaces. *Energies* **2022**, *15*, 5553. [CrossRef]
140. Bergmann, N.; Schacht, S.; Gnewuch, U.; Maedche, A. Understanding the Influence of Personality Traits on Gamification: The Role of Avatars in Energy Saving Tasks. In Proceedings of the 38th International Conference on Information Systems (ICIS), Seoul, Rrepublic of Korea, 10–13 December 2017.
141. Mendez, J.I.; Ponce, P.; Mata, O.; Meier, A.; Peffer, T.; Molina, A.; Aguilar, M. Empower Saving Energy into Smart Homes Using a Gamification Structure by Social Products. In Proceedings of the 2020 IEEE International Conference on Consumer Electronics (ICCE) 2020, Vegas, NV, USA, 4–6 January 2020; pp. 1–7. [CrossRef]
142. Takayama, C.; Lehdonvirta, V.; Shiraishi, M.; Washio, Y.; Kimura, H.; Nakajima, T. ECOISLAND: A System for Persuading Users to Reduce CO_2 Emissions. In Proceedings of the 2009 Software Technologies for Future Dependable Distributed Systems, Tokyo, Japan, 17 March 2009; pp. 59–63.
143. Schultz, P.W.; Estrada, M.; Schmitt, J.; Sokoloski, R.; Silva-Send, N. Using In-Home Displays to Provide Smart Meter Feedback about Household Electricity Consumption: A Randomized Control Trial Comparing Kilowatts, Cost, and Social Norms. *Energy* **2015**, *90*, 351–358. [CrossRef]
144. The European Commission. *(2012/148/EU) Commission Recommendation of 9 March 2012 on Preparations for the Roll-Out of Smart Metering Systems*; European Commission: Brussels, Belgium, 2012.

145. Barai, G.R.; Krishnan, S.; Venkatesh, B. Smart Metering and Functionalities of Smart Meters in Smart Grid—A Review. In Proceedings of the 2015 IEEE Electrical Power and Energy Conference (EPEC), London, ON, Canada, 26–28 October 2015; pp. 138–145.
146. Ibrahim, C.; Mougharbel, I.; Kanaan, H.Y.; Daher, N.A.; Georges, S.; Saad, M. A Review on the Deployment of Demand Response Programs with Multiple Aspects Coexistence over Smart Grid Platform. *Renew. Sustain. Energy Rev.* **2022**, *162*, 112446. [CrossRef]
147. Cetin, K.S.; O'neill, Z. Smart Meters and Smart Devices in Buildings: A Review of Recent Progress and Influence on Electricity Use and Peak Demand. *Curr. Sustain. Energy Rep.* **2017**, *4*, 1–7. [CrossRef]
148. Beckel, C.; Sadamori, L.; Staake, T.; Santini, S. Revealing Household Characteristics from Smart Meter Data. *Energy* **2014**, *78*, 397–410. [CrossRef]
149. Kavousian, A.; Rajagopal, R.; Fischer, M. Determinants of Residential Electricity Consumption: Using Smart Meter Data to Examine the Effect of Climate, Building Characteristics, Appliance Stock, and Occupants' Behavior. *Energy* **2013**, *55*, 184–194. [CrossRef]
150. Méndez, J.I.; Ponce, P.; Meier, A.; Peffer, T.; Mata, O.; Molina, A. S4 Product Design Framework: A Gamification Strategy Based on Type 1 and 2 Fuzzy Logic. In *Games and Learning Alliance*; Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics); Springer: Berlin/Heidelberg, Germany, 2020; Volume 12015, pp. 509–524.
151. Rotondo, J.; Johnson, R.; Gonzales, N.; Waranowski, A.; Badger, C.; Lange, N.; Goldman, E.; Foster, R. *Overview of Existing and Future Residential Use Cases for Connected Thermostats*; Energetics Inc.: Washington, DC, USA, 2016.
152. Zhang, Y.; Prouzeau, A.; Khalajzadeh, H.; Goodwin, S. Toward Improving Building User Energy Awareness. In Proceedings of the e-Energy 2020–11th ACM International Conference on Future Energy System, Online, 22–26 June 2020; Volume 5, pp. 539–543. [CrossRef]
153. Wood, G.; van der Horst, D.; Day, R.; Bakaoukas, A.G.; Petridis, P.; Liu, S.; Jalil, L.; Gaterell, M.; Smithson, E.; Barnham, J.; et al. Serious Games for Energy Social Science Research. *Technol. Anal. Strat. Manag.* **2014**, *26*, 1212–1227. [CrossRef]
154. Dimitriou, N.; Garbi, A.; Vasilakis, K.; Schoofs, A.; Taha, A.; Nikiforakis, M.; Kotsilitis, S.; Papaioannou, T.G.; Kotsopoulos, D.; Bardaki, C.; et al. ChArGED: Implementing a Framework for Improving Energy Efficiency in Public Buildings through IoTenabled Energy Disaggregation and Serious Games. In Proceedings of the 2018 IEEE International Conference on Pervasive Computing and Communications Workshops (PerCom Workshops), Athens, Greece, 19–23 March 2018; pp. 65–70. [CrossRef]
155. Rist, T.; Masoodian, M. Promoting Sustainable Energy Consumption Behavior through Interactive Data Visualizations. *Multimodal Technol. Interact.* **2019**, *3*, 56. [CrossRef]
156. Kotsopoulos, D.; Bardaki, C.; Pramatari, K. Gamification, Geolocation and Sensors for Employee Motivation Towards Energy Conservation at the Workplace. In Proceedings of the 2016 Mediterranean Conference on Information Systems (MCIS), Paphos, Cyprus, 4–6 September 2016.
157. Beck, A.L.; Chitalia, S.; Rai, V. Not so Gameful: A Critical Review of Gamification in Mobile Energy Applications. *Energy Res. Soc. Sci.* **2019**, *51*, 32–39. [CrossRef]